REVIEW OF MATERIALS PROCESSING IN SPACE
1983

HEARINGS
BEFORE THE
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SPACE SCIENCE AND APPLICATIONS
OF THE
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U.S. HOUSE OF REPRESENTATIVES
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Dr. Jacob C. Stucki, vice president for pharmaceutical research, the Upjohn Co., Kalamazoo, Mich.; Dr. Merton Flemings, professor, Materials Processing Center, Massachusetts Institute of Technology, Cambridge, Mass., accompanied by George B. Kenney, assistant director, Materials Processing Center, Massachusetts Institute of Technology, Cambridge, Mass.; Dr. Dudley A. Saville, Department of Chemical Engineering, Engineering Quadrangle, Princeton University, Princeton, N.J.; and Dr. Milan Bier, professor, Biophysics Technology Laboratory, Electrical Engineering Building, University of Arizona, Tucson, Ariz...... 66

REVIEW OF MATERIALS PROCESSING IN SPACE 1983

WEDNESDAY, SEPTEMBER 14, 1983

House of Representatives,
Committee on Science and Technology,
Subcommittee on Space Science and Applications,
Washington, D.C.

The subcommittee met, pursuant to call, at 9:45 a.m., in room 2325, Rayburn House Office Building, Hon. Harold L. Volkmer (chairman of the subcommittee) presiding.

Mr. Volkmer. The subcommittee will come to order.

Today we'll have our first of two oversight hearings on NASA's program of materials processing in space. The second hearing will be held tomorrow in this same room.

Dr. Richard Halpern, NASA program manager, will be our first witness by reviewing his program for us. We'll also—we'll also hear from Dr. Guy Rindone, who represents the Universities Space Research Association.

The Committee on Science and Technology has consistently urged NASA to increase its effort in this area because we feel there is great potential. The committee has added funding to the NASA request in each of the three last authorization bills. We added $4 million in fiscal year 1982, $5 million in fiscal years 1983 and 1984.

In our 1983 committee report, we urged NASA to expand the materials science and engineering base in the university community. In the fiscal 1984 report for the year that will begin in a few days, the committee asked NASA to do several things: First, to establish at a university a center for basic research on separation and purification of organics. We will hear more about that tomorrow. Second, augmentation of research with private firms with a view toward commercial applications. Third, that NASA not put large additional resources in hardware until it has a better defined sense of direction for this program.

Finally, we asked that NASA prepare an annual report on the program.

The committee has been aware of the "1978 Report of the National Academy of Sciences on Materials Processing in Space" which criticized early NASA efforts as weak. The report recommended generally that problems proposed for investigation in space have, from the outset, a sound base in terrestrial science or technology and their proposed experiments address scientific or technical problems that are not motivated primarily to take advantage of flight opportunities or capability of the space facilities.

We believe that the NASA program has been strengthened considerably since that report, but it can be stronger. We have a new program manager in Dick Halpern and we want to make him—and help him get off to a good start.

[The prepared statement of Mr. Lujan follows:]

PREPARED STATEMENT OF HON. MANUEL LUJAN, JR.

Thank you, Mr. Chairman, the recent series of successful shuttle launches sets the background for these hearings. The development of commercial potential of space is a principal mission of the shuttle. NASA has been studying the potential for space manufacturing for over 10 years now. The hearings we held earlier this year made it clear that materials processing is the next major area for commercial development of space. The great economic success of communication satellites should serve as an indication of the potential economic benefits of materials processing in space. In fact, space processing of new materials and pharmaceutical products may be the most effective early payoff from the shuttle. Obviously, pharmaceutical products would provide immediate, identifiable benefits for the well-being of mankind.

To develop the potential for materials processing in space will require three main efforts. The first effort is the basic research into understanding the effect the space environment such as microgravity will have on processing. The second aspect is to translate this basic research into practical applications. The third aspect is the development of the equipment and technology to do both of the basic research and the applications development.

Hopefully, this hearing will allow us to examine the relative proportion of the these three aspects in the program.

Mr. **VOLKMER**. Dr. Halpern, let me welcome you to this hearing and say that we're looking forward to your testimony today. Longer term, we look forward to working with you to make an even better NASA program for materials processing.

Now, your statement, Dr. Halpern, will be incorporated and made a part of the record. You may review the statement in total or summarize it, however you see fit.

STATEMENT OF DR. RICHARD HALPERN, DIRECTOR, MATERIALS PROCESSING, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Dr. **HALPERN**. Thank you very much, Mr. Chairman, Mr. Walker. I appreciate the opportunity to come here today and tell you about our program in materials processing in space. I have submitted a statement for the record, Mr. Chairman, and I would like to make just a few oral remarks.

First of all, as I indicated in my written testimony, there is a proposed name for our division, which is to be called microgravity science and applications. I'd like to spend just a moment explaining to you and the other committee members the reason for that change.

Mr. **VOLKMER**. All right. Would you pull the microphone a little closer to you?

Dr. **HALPERN**. Is that better?

Mr. **VOLKMER**. A little better. Just a little bit closer yet.

Dr. **HALPERN**. All right.

Mr. **VOLKMER**. Now, I think we'll do fine.

Dr. **HALPERN**. All right, fine. Thank you.

Microgravity Applications and Science is the proposed name of the new division. The reason for the name change is primarily to expand our scientific base and the applied research that we plan to do.

We believe it's more descriptive of the kind of work that we will be actually doing. The former name, Materials Processing in Space, of course, is historical and dates back to a time prior to the merger of the Space Science Office and the Applications Office at NASA. It is our plan to open up the use of space and particularly the microgravity applications and an example that I might bring to your attention is the fact that under our new charter, we are going to become involved in, among other things, the combustion field, which has very direct terrestrial applications. Under the former name, there was some concern that this might not be an appropriate area of research, but we believe, under the present charter, it most definitely is.

Just a word about our current program. There has been some confusion, perhaps, at times, and some misunderstanding about what we're trying to do. Let me revert back to the former name and talk about Materials Processing in Space because it is a very diverse field.

The current program consists of work in solidification on metals, on glasses, ceramics, and so forth. It also is concerned with growing crystals in this space environment. We are doing some work in bioprocessing, and as you mentioned in your opening statement, Mr. Chairman, we will follow the guidelines of this committee and be doing more work in the bioprocessing area.

Currently, we have work ongoing at the University of Arizona and Professor Bier will be a witness before this subcommittee tomorrow, I believe. We also have some work in basic electrophoresis at the Johnson Spacecraft Center in Texas and also some work at Penn State University under Paul Todd. We are doing some work in the electrophoresis techniques at the Marshall Space Flight Center under Dr. Bob Snyder.

Another area that we are actively pursuing in our current program is the area of containerless processing. Space offers us the opportunity to work with materials without any kind of container, which, of course, is needed on Earth under gravity conditions. The primary attribute of this particular process is that there will be no contamination of the material under investigation by the container in which it's held, and, therefore, we have the opportunity of producing very, very pure materials.

Currently, we're active in three areas of levitation work: acoustics, electrostatic work, and electromagnetic work. The potential in this area, among other things, is to produce high-temperature glasses and we are, in that sense, working actively in the electrostatic levitation mode.

The final area that I'd like to touch on briefly in our present program is that of commercialization. This, of course, is—has become very prominent in the last year or so. There has been a lot of discussion about high-technology work and the ability of the American industry to compete with other world powers.

At the present time, NASA is involved in two joint endeavor agreements; one, of course, with Mc-DAC in the electrophoresis field; the second with Microgravity Research Associates, who hope to build pure crystals in space. I am personally very interested in furthering this kind of endeavor. As a matter of fact, I had a meeting yesterday with another industrial organization that's interested in coming into the space work and we hope to pursue the JEA's in the future. We also have another area of work with industry that is lesser known and that is the Technical Exchange Agreement where NASA and an industrial partner agree to do Earth research and in that particular arena, we are currently working with Dupont, Deere, INCO, and Minneapolis Honeywell and again, we hope to increase the number of industrial concerns that we are working with in the future.

As far as the future program is concerned, first of all, let me assure the subcommittee that we will take your recommendations and guidelines very much into account in what we do in 1984 and subsequent. In particular, we intend to honor your mandate and proceed to establish one or more university centers for bioprocessing research.

As a matter of fact—as soon—I have to say this, Mr. Chairman, as soon as it was known that this was being recommended and ultimately the Appropriations Committee came through with additional moneys for NASA, I won't say I was inundated with suggestions or intent to propose for the center, but a number of people have already contacted me. It is my intent to issue in the near future an announcement in the nature of a—probably a "Dear Colleague" letter and request from interested university centers intent to propose for such a research facility.

At the same time, I expect to be working with the Space Applications Board, as well as the National Institutes of Health, in order to establish criteria on which to evaluate and select appropriate proposals for such research centers. As I'm sure you're aware, NASA is not, in and of itself, medically expert and I would hope to be able to establish through the Institutes of Health a peer review process for the evaluation of these proposals.

In addition to—to establishing those centers, it is our intent to emphasize in the future small, relatively low-cost middeck-type experiments so that we can obtain longer duration microgravity exposures for the work that we have ongoing.

The—the field of microgravity research is really just emerging. We have not had in the past the facilities to accommodate long durations in space and as a result, a good bit of our work has been done on the ground. We have had some exposures in space, but not of—of any great magnitude. Certainly, nothing compared to the more traditional science areas that have a—have a history that may go back several hundred years.

The total time of zero-g exposure for our research program may be measured in order—in the order of hours, perhaps a day or two, and it is my intent in—in the future, using the resources that have been given to the division, to try to expand that program. We will certainly take into account your guidance and not build large expensive pieces of hardware, but in order to move our research program forward, we will require small apparatus of a such—of such a size as I mentioned before that can fit, perhaps, into the middeck of the shuttle.

I think, Mr. Chairman, that that will give you some idea of where we expect to go in the future and I will conclude my oral remarks with those statements. If there are any questions that I may try to answer, I'd be glad to try to accommodate them now.

[The prepared statement, plus answers to questions asked of Dr. Halpern, follow:]

HOLD FOR RELEASE
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BY WITNESS
SEPTEMBER 14, 1983

Statement of

Mr. Richard E. Halpern
Director, Microgravity Science and Applications Division
Office of Space Science and Applications

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

before the

Subcommittee on Space Science and Applications
Committee on Science and Technology
House of Representatives

Mr. Chairman and Members of the Subcommittee:

I am pleased to be here today to present testimony concerning the content of the NASA's program for Materials Processing in Space. As the Director of the Division in which that program currently resides, I represent the Agency in all matters related to materials processing in space, including the basic research as well as the materials processing applications. I will describe briefly our history, our current operation, and where the Division is heading in the future. A new name for the Division is currently being proposed: Microgravity Science and Applications. The purpose of this change is to expand the Division's charter scientifically and to emphasize the Applications role.

The Beginning

NASA's interest in space processing began to evolve in the late 1950's and early 1960's from several different disciplines. The behavior of fluids in spacecraft was the object of a number of research efforts in order to design propellant management systems for liquid upper stages. The first low-gravity solidification studies were prompted by the requirement to design spacecraft thermal control systems that used latent heat of solidification for thermal energy storage. The requirement for joining structural members in space to erect large space structures by welding and brazing raised questions about the influence of gravity in these processes. Drop towers at the Lewis Research Center (LeRC) and the Marshall Space Flight Center (MSFC), as well as KC-135 aircraft, were used to investigate many of these phenomena.

The first opportunities to perform long duration experiments in low-gravity came with the Apollo lunar program. The experiments consisted of a low-temperature furnace to perform casting experiments on model composite systems, a heat flow and convection experiment, and a primative electrophoresis experiment to test the concept of performing electrophoretic separation of pharmaceuticals in the absence of buoyancy driven flows which limit the process on earth.

Skylab offered the first opportunity to perform materials processing experiments in a dedicated facility. The experiments consisted of welding and brazing investigations, a study of combustion in a diffusion controlled environment, several solidification experiments involving composites, five crystal growth experiments, and an unsuccessful attempt at containerless solidification.

The Apollo-Soyuz Test Project (ASTP) offered an opportunity to fly several new experiments as well as to refly several of the Skylab experiments that had produced provocative results.

In general, the experiments performed on Apollo, Skylab, and ASTP did not produce spectacular results, but did confirm that buoyancy-driven convective flows were sufficiently suppressed so that diffusion controlled conditions could be realized. Also, several unexpected results were discovered. For example, Dr. H. Wiedemeier (Rensselaer Polytechnic Institute) found significantly higher growth rates in his crystal growth experiment using chemical vapor transport than were expected. Dr. D. Larson (Grumman Aerospace Corporation) found unusual magnetic properties in a sample of manganese bismuth directionally solidified in space which were later attributed to a finer microstructure.

The long hiatus in manned spaceflight opportunities between ASTP and Shuttle precluded additional long duration space experiments in which samples could be readily recovered for analysis. As an interim measure, a series of Space Processing Application Rocket (SPAR) flights were initiated. These flights, using Black Brandt rockets, could carry as many as four small experiment packages and provide up to five minutes of free fall time. Acoustic and electromagnetic levitation techniques were developed to position samples for containerless processing. The influence of gravity on the structure of castings was thoroughly studied with experiments at elevated gravity using a centrifuge and at reduced levels using SPAR rockets. An improved directional solidification furnace was developed, and the unexpected behavior of manganese bismuth eutectic growth observed by Larson on his ASTP experiment was studied using a series of flights at different growth rates.

In 1978, the Space Applications Board of the National Research Council conducted a study on the practical applications of space. To perform this study, an ad hoc committee, the Committee on Scientific and Technical Aspects of Materials Processing in Space (STAMPS), was established.

The committee concluded that a valid scientific basis exists for performing certain classes of experiments in space, although they did not see any processes for producing materials in space that were economically justifiable. They were critical of the fact that some of the early experiments lacked careful planning, were inconclusive, and received undue publicity. It was noted, however, that the experiments that yielded useful results had a sound base in terrestrial research.

The committee recommended that NASA proceed with the Materials Processing program in two phases. Phase One should extend over the first five years of Shuttle operation and should be dedicated to delineating the potentials and limitations of performing materials science experiments in space. If the results obtained in Phase One convincingly demonstrate the usefulness of carrying out experiments in microgravity, Phase Two would evolve into a National Microgravity Laboratory using the Space Shuttle in conjunction with other space facilities, (e.g., Spacelab, various free-flyers, and possibly a space station).*

*NASA is essentially carrying out the STAMPS recommendations.

The Current Research Program

The primary purposes of the current program are: (1) to explore and identify fruitful areas for microgravity research; (2) to understand how gravitational effects limit certain earth-based processes, and how such limits may be overcome, either by better controlling strategems on earth or by use of the microgravity environment of space; (3) to develop university centers of excellence where results obtained in space may be compared to the best available earth techniques; and, (4) to develop the necessary technology and apparatus for carrying out the various space experiments.

Approximately 100 investigators currently make up this science base. Proposals for various research tasks are selected on the basis of scientific merit, established by a peer review process, and program relevance. Additionally, work on materials is being conducted at five NASA Centers; Marshall Space Flight Center, Jet Propulsion Laboratory, Johnson Space Center, Lewis Research Center, and Langley Research Center.

The evolution of the program is evident from the number of papers published in refereed journals. This number has increased from a few dozen before 1977 to 168 published last year. These figures reflect the growth in the science base and the maturation of the program, as well as the important contributions made to the study of materials science. We are currently pursuing work in the following material processing areas: (1) Crystal Growth, (2) Solidification, (3) Containerless Processing, (4) Bio-Separation Processing, and (5) Commercial Activities. Some of the more significant results are summarized in the following paragraphs.

Most industrial processes for crystal growth in use today evolved empirically with little theoretical understanding. Only recently have crystal growers begun to analyze convective flows and how they affect the growthh process. The NASA-sponsored program investigating the processing of materials in a microgravity environment is largely responsible for this evolution.

The flows associated with crystal growth are complicated by the fact that most systems of interest have more than one component, hence, both thermal and compositional effects must be considered. Therefore, it is necessary to model the combined thermal-solutal or double diffusive convection. We are working on the special techniques needed to analyze such problems.

Dr. F. Rosenberger (U. Utah) has extensively analyzed convection in closed tube vapor crystal growth and finds that viscous interactions between the transporting vapor and the container wall creates density gradients that are always convectively destabilizing; hence, it is not possible to achieve diffusion controlled vapor transport in a gravity field. Further, he finds that the accepted models for diffusional-vapor-transport work as well as they do only because they contain self-cancelling errors. Convection is virtually always present in earth-based processes and cannot be avoided. This may provide an explanation for the anomalous result that Wiedemeier found in comparing his Skylab experiment to what was thought to be diffusion controlled transport on the ground.

Early attempts to study solidification of monotectic alloys (systems that have liquid phase miscibility gaps) in a microgravity environment indicated that other mechanisms that do not involve gravity are also important. Recent work on model systems has revealed some interesting insights into some of the mechanisms. Dr. John Cahn (NBS) showed in 1979 that such systems would be unstable if the lesser alloy wet the container in preference to the major alloy. There is a temperature range near the critical temperature in which one of the two phases becomes perfectly wetting and will intrude between the container (or free surface) and the other phase. If the minority phase becomes perfectly wetting, droplets nucleating on or near the outer surface will immediately spread over the entire surface. The flows produced by such spreading will bring other droplets near the surface where they will undergo a similar fate.

Understanding such mechanisms may allow us to control phase separation in such alloy systems and produce fine in situ dispersions in some of the large number of binary systems that have liquid phase miscibility gaps. Thus, it may be possible to obtain interesting electrical properties, especially in metal-semiconductor systems.

Since liquids, especially high temperature melts, can be contained solely by their surface tension and positioned in a microgravity environment by small non-contacting forces provided by electrostatic, electromagnetic, or acoustic fields, there are a number of potential applications for containerless processing in space. Ultra-high purity can be maintained even in highly corrosive melts at elevated temperatures. Thermophysical properties at very high temperatures can be measured. Deep undercooling can be obtained which can result in solids with unique microstructures.

The range of glass formation may be extended in many systems and new glasses with unique properties may be possible, e.g., halide (glasses that are transparent in the infrared for use in low-loss optical fibers).

Considerable work has been done on levitation technology at JPL. Techniques for positioning and rotating samples using acoustic fields (suitable for sample to be procesed in a gaseous environment) and electrostatic fields (for processing in vacuum) have been developed and extensively tested in KC-135 aircraft and SPAR rocket flights. A 3-axis acoustic levitator furnace is being developed for use on the Space Shuttle.

Following the recommendations of the STAMPS Committee, NASA has made considerable progress in understanding continuous flow electrophoresis and the limitations imposed by operating such separation devices in earth's gravity. Work is underway at MSFC and JSC on the basic theory as well as applied work in conjunction with the McDonnell-Douglas STS research effort.

A recirculating isoelectric focusing separator has been developed by Professor M. Bier (U. Arizona). Isoelectric focusing has a major advantage over electrophoresis in resolution since the sample bands are self-sharpening. Also, the isoelectric point tends to be a more specific discriminator than electrophoretic mobility which allows separations to be made by isoelectric focusing that cannot be made by electrophoresis. A series of Shuttle experiments is being developed by Dr. Bier.

In evolving the program from one in which all research is sponsored by NASA toward the Phase Two program recommended by the STAMPS Committee, NASA has developed several mechanisms to involve the potential user community. One of these is the Joint

Endeavor Agreement (JEA).

The JEA was designed to achieve the objective of national technological superiority with U.S. domestic concerns. It is generally, but not limited to, an arrangement whereby NASA and a prospective user can share the costs and risks of developing commercial space ventures. There is no exchange-of-funds. Generally, the company is expected to develop the experimental apparatus; NASA in turn agrees to provide a specified number of flights in return for various considerations, e.g., data rights, use of facility, etc. If the venture then becomes commercial, the company reimburses NASA for future flights. Two such JEA's are in effect; one with McDonnell-Douglas Aerospace Corporation and the other with Microgravity Research Associates.

A second area of work with U.S. industry is the Technical Exchange Agreement (TEA). The purpose of a TEA is to allow an industrial firm to work with NASA on a no exchange-of-funds basis in areas of mutual interest. Under such an agreement, a company may conduct experiments in NASA ground-based facilities including drop tubes, drop towers, and aircraft in order to determine whether a more elaborate space experiment is justified. Samples have been processed in the MSFC drop tube and KC-135 aircraft for John Deere and Dupont under this type of agreement. Also, joint studies of convection in electrodeposition have been carried out in conjunction with INCO and studies of the growth and purification of mercury cadmium telluride are in progress with Minneapolis Honeywell Electro-optical Division.

The Current Flight Program

The Materials Processing in Space Flight Program has just begun. A few modest, but well conceived experiments have already flown on the Space Transportation System (STS) and more will certainly follow.

A series of seeded polymerization experiments, using the Monodisperse Latex Reactor, beginning with STS-3 were conducted by John Vanderhoff (Lehigh U.). The objective of this series of experiments is to produce precision polystyrene spheres with uniform sizes that can serve as calibration standards. When this effort was initiated, precision sized spheres in the 2-40 micrometer range were not available in quantity. Spheres smaller than 2 micrometers could be produced by seeded polymerization, but the stirring required to keep the larger sizes in suspension during the polymerization process often resulted in agglomeration or flocculation.

Improvements in earth-based technology can now provide particles in this size range with size dispersions on the order of 3%. However, these particles are not completely spherical. The particles produced by Vanderhoff on the Shuttle have dispersions less than 1% and appear to be perfectly spherical, as verified by independent analysis by the National Bureau of

Standards. In fact, the NBS has determined that these particles qualify as calibration standards and has requested additional particles for this purpose.

Six material samples were flown in two General Purpose Rocket Furnaces (GPRF's) as part of the OSTA-2 payload on STS-7. One furnace was configured for isothermal processing and the other configured for gradient processing. The furnaces functioned properly and produced the required thermal profiles in the samples.

Dr. Gelles (S. H. Gelles Associates) flew several monotectic alloys. One sample was processed in the gradient furnace to examine the effects of thermal migration of the minority phase droplets driven by thermocapillary flows. Other samples, processed in the isothermal facility, had spring loaded plungers to eliminate free surfaces and possible surface tension driven flows. The samples are presently being analyzed.

Dr. Wiedemeier repeated his earlier Skylab experiment involving vapor crystal growth of germanium selenide except that an inert gas was substituted for the iodine transport gas used previously. The purpose was to determine if the previously observed anomalous transport rates were in fact caused by chemical reactions throughout the growth ampoule, or whether other mechanisms must be sought. The results are not yet available.

One unexpected result was observed, however. The crystals grown in space were almost an order of magnitude larger than those grown under identical thermal conditions on the ground. Very well-defined platelets, some as large as 5X10 millimeters, grew in an open web-like structure in the flight ampoules, whereas the ground control ampoules contain a crust of very small crystals in the growth region. At the present, we have no explanation for this striking difference in growth morphology.

A third experiment in containerless processing failed to operate properly because of a mechanical malfunction. It is under examination and will be repaired and re-flown in 1984.

Spacelab 1 and Spacelab 3 have MPS experiments planned. These will include activities in crystal growth, containerless processing and solidification. Mid-deck experiments in bio-processing will also be flown in 1984.

The Future Program

The first aspect of NASA's future program must be an increased emphasis on flight experimentation on the effects of microgravity. Within the available resources, it is the intent of the Microgravity Sciences and Applications Division to provide increased opportunities through use of the STS Middeck facilities. This should allow relatively low cost experimental flights on a recurring basis using apparatus which can be devised within a period of about two years. It is absolutely imperative that the promise of the low gravity environment be thoroughly explored by this means.

Follow-on experimentation of increased sophistication, perhaps using facilities capable of handling several samples, will naturally follow the use of the Middeck facilities. These in turn, will act as the transition or bridge between experimentation whose duration is on the order of hours, or perhaps days, to the potential application of instrumentation suitable for use on a future Space Station where durations of weeks to months will be possible.

As you are aware from earlier testimony, NASA has been studying potential requirements for a permanent space station. Candidate materials processing missions have been identified which would benefit from the continuous presence and servicing capabilities of man.

The second aspect of the future program, which goes hand in hand with the emphasis on increased flight opportunities, is that of a shift in program content. While the emphasis of the mid-70's was on ground operations and properly establishing a scientific data base, the advent of the Space Shuttle brings with it the opportunity for providing the potential of materials processing in an applied research function. Together with the increased interest in commercialization of the materials processing field, the applied research base can be expected to expand.

In research domains as vast and multidisciplined as the physical, biological, or materials sciences, NASA must be cautious to avoid funding research efforts, however worthy, that would be more appropriately funded through other government agencies. For this reason, research tasks supported by the microgravity science base should meet one or more of the following criteria:

1. Research should be in an area in which there is reason to believe that the investigation could be enhanced by performing experiments in a microgravity environment.

2. Research should determine influence of gravity on a particular process in order to establish the limitations imposed by earth's gravity, or to explore ways of circumventing such limitations.

3. Research should support existing flight experiments or flight development experiments by measurement of needed physical

properties, modelling of temperature and flow fields, development of needed instrumentation and special purpose apparatus, or any other effort required to define and develop, establish the rationale, or interpret the results from such experiments.

In order to direct our activities toward increased applications, we intend to establish an external working group that will include a relatively high percentage of industrial representatives. While we would like to be able to tell the Committee that NASA can choose which areas are most suitable to industrialization, we are not able to do so. Indeed, Mr. Beggs, the NASA Administrator, has stated that NASA is not in the position to decide which areas of the space business are best suited for commercialization. He feels, that that is up to the private sector; however, Mr. Beggs has further stated that NASA intends to receive all suggestions and assist any company interested in commercializing a part of the space business. The Microgravity Science and Applications Division will participate actively in that endeavor. We are working with NASA's Task Force on Commercialization to make access to space more routine, thereby encouraging greater U.S. Industrial participation.

We believe that NASA must create an atmosphere and the framework for enhanced technological research and commercialization; but we also believe the private sector is ultimately going to have to make the deccisions on which technologies to pursue, and to decide on which areas are likely to lead to industrialization and commercialization.

The two specific areas which, at the present time, have indications of enhanced commercialization promise are the fields of bioprocessing and pharmaceutical research and semi-conductor crystals. The products of both of these areas have an enormous value per pound of materials produced and, therefore, are currently thought to be most amenable to commercialization, when one considers the relatively high cost of processing in space.

One area that should be discussed specifically is the area of bioprocessing and pharmaceutical research. In accordance with congressional desires, and specifically in the spirit of both the House and Senate Authorization Bills, we will begin in Fiscal Year 1984 to establish one or more University Centers to do pharmaceutical research.

We plan to issue, within the next half year, a document similar to a "Dear Colleague" announcement to university groups and to solicit from these groups indications of interest in establishing such a research facility. It is expected that many of these universities will respond to such an announcement with an indication, not only of a solid research facility, but with a tie into industrial and pharmaceutical organizations.

We are in the process of establishing criteria upon which to judge such proposals. The establishment of these criteria will be done jointly between the Office of Space Science and Applications, the Space Applications Board, and the National Institutes of Health. These criteria will be widely publicized so that the establishment of the centers can be done on an equitable basis.

Another aspect that the future program of the Microgravity Science and Applications Division will undertake is that of increased international cooperation. Many countries such as the Western European nations and Japan have concentrated efforts in microgravity research. They have devoted their budgets to the use of sounding rockets and small self-contained payloads and the building of large, complex facilities for microgravity science. Once such facility, the Materials Science Double Rack, was produced for the European Space Agency by the Federal Republic of Germany and will fly initially on Spacelab-1 later this year. To take advantage of equipment already developed both in the U.S. and abroad, NASA is considering the establishment of an International Microgravity Laboratory (IML) as part of our Spacelab utilization program. The IML would be a collection of compatible materials processing and life sciences apparatus to fly periodically on the Space Shuttle with an opportunity for refurbishment and upgrading of the equipment between flights. NASA would provide the launches at no cost in return for use of the foreign-developed facilities by U.S. scientists and access to the data from experiments conducted by scientists from other countries. This pooling of resources will result in an expanded U.S. research program.

One final item, Mr. Chairman. In accordance with the desires of Congress, we are in the process of preparing our first annual program report. This report will be submitted in December of this year and annually thereafter. It will include highlights of the past year, our current activities, and our future directions in both basic and applied research. We hope this document will serve your needs and will also be useful in making the private sector aware of our work.

In conclusion, Mr. Chairman, I wish to thank you and the other members of this subcommittee for your support, and through our program in the next year, I hope to be able to convince you that we merit your continued support

Written questions from the September 14, 1983, hearing at which Mr. Halpern testified on materials processing.

Question 1:

a. Other than bioprocessing, do any other opportunities exist in materials processing in space to warrant the establishment of university centers?

b. If so, is it feasible to establish a single multidisciplinary center?

c. Would sufficient strong technical relationships exist that would promote cross-fertilization between such disciplines?

Answer 1:

a. The Microgravity Sciences and Applications Division sponsors several areas (e.g. crystal growth, alloy solidification, etc.) that have potential opportunity for materials processing in space which warrants the establishment of a university center.

b. It is entirely feasible to establish a single multidisciplinary center; however, to provide for the establishment of such a center would require a very large initial investment on the Government's part. We believe it is better to establish a single discipline-oriented center which, in a university setting, may then expand in to multidisciplines. The Materials Processing Center at the Massachusetts Institute of Technology is an example of how this may evolve. The center was initially started with primary emphasis on solidification work. However, after a short period of time, the center was supported not only by NASA but by DOD and private industry. It currently involves faculty members in the materials science, mechanical engineering, electrical engineering, chemical engineering and physics department. The seed money from NASA has thus grown in many different directions.

c. As noted above, sufficiently strong technical relationships do exist within university departments and do promote cross fertilization between various disciplines of engineering, physics and materials sciences.

Question 2:

Does a university setting represent any advantage over a national laboratory or industrial facility in stimulating progress in space materials processing research? Could this also be accomplished through a centralized multi-university facility?

Answer 2:

NASA believes there are some advantages in the use of a university for stimulating progress in space materials research because of the academic atmosphere at the university. In such an atmosphere, there is no inhibition on research and no bounds to innovation other than the imagination of the researcher. We are currently using various NASA field centers, the National Bureau of Standards Laboratory and the Institute for Theoretical Physics, as well as the university arena for research in microgravity science and applications.

A centralized multi-university facility may eventually evolve; but, it is NASA's belief that the seed must be planted at a single university and allowed to grow in accordance with the research opportunities which come along.

Question 3:

What type of managerial and programmatic relationships between NASA and the proposed center would lead to the most productive research environment?

Answer 3:

Close working relationships must be maintained between the proposed center and the various NASA centers engaged in similar research. The research topics proposed by the center should be reviewed by NASA to insure relevance to the Microgravity Science Programs.

Question 4:

Could the science working groups constituted under the USRA aegis function in an advisory capacity for the university center?

Answer 4:

A close working relationship between the appropriate science working groups and the proposed center is expected. In fact, representatives from the center would serve on such working groups. However, it is important that the university not be inhibited in their research program by too close an oversight.

Question 5:

What do you believe should be the criteria for selection of the university center?

Answer 5:

As I stated in my testimony, these criteria will be established jointly between the Office of Space Science and Applications, the Space Applications Board, and the National Institutes of Health. We are now in the process of drafting these criteria and expect to have them completed before the end of the year.

Question 6:

What size center should be considered appropriate for establishing a viable program in materials processing? What would be a favorable balance of principal researchers, post-doctoral students, graduate students, visiting researchers, etc?

Answer 6:

The initial size that the center is likely to be depends, at least in part, on the funding available to the university. As I stated, this has not yet been decided, but will be based on the proposals submitted in response to the announcement to be issued. The balance of principal researchers, post-doctoral students, graduate students, visiting researchers, etc., proposed will be a factor in judging the proposal by those people constituting our review committee who have a background in the medical and pharmaceutical fields. Ultimately, of course, it is our expectation that the planned funding to initiate the establishment of the center will be seed money and, as the center grows, we envision a change in the balance of those people participating at the center.

Question 7:

What relationship would be appropriate between industry and the university center?

Answer 7:

NASA believes that the pharmaceutical industry would eventually co-sponsor a center very much in the manner in which the MIT Center for Materials Processing is co-sponsored. This would give the center a much broader base and would encourage the development of new separation and purification processes that require microgravity. Additionally, it is expected that such a center could ultimately begin involving itself in research, based on requirements of industrial organizations processing materials under the effect of gravity (on earth).

Question 8:

In your testimony, you spoke of the need for medical and biological scientists on the advisory committee for the proposed university center for bioprocessing.

Would the participation of scientists from other disciplines (e.g., physical chemists, chemical engineers, etc.) also be of assistance in understanding the separation phenomena and guiding the research?

Answer 8:

There is a need for medical and biological scientists on the review committee of proposals for the univerisity center for bioprocessing rather than on an advisory committee. The participation of other disciplines such as physical chemists, chemical engineers, fluid dynamicists, etc., are an essential part of such a center. Real progress has been made in other fields of materials science where such an interdisciplinary approach has been taken.

Question 9:

Under the present proposal system, how is program relevance determined?

Answer 9:

Program relevance is currently determined largely on the subjective knowledge of the reviewer, who is considered to be an expert in the field, and who is familiar with the microgravity science and applications program. Reviewers are asked to comment on relevance of the proposed work to NASA's microgravity program. Such comments are taken in consideration when determining the particular research tasks to fund.

Question 10:

Currently, what type of work are you pursuing in the "commercial activities" program area?

Answer 10:

Current work in the "commercial activities program" involves several different facets. We publicize basic research results through accredited journal articles, conferences, seminars, and personal contacts with industrial organizations; thus, they are kept aware of possible commercial opportunities emanating from the MPS program.

We are working with both the McDonnell-Douglas Corporation and Microgravity Research Associates through joint endeavors and assisting them as required with information and technical consultation. Our scientists are currently working with the Dupont Corporation, Upjohn Inc., John Deere, Inc., and International Nickel Corporation on existing Technical Exchange Agreements. We have had inquiries from a number of private companies that have expressed interest in commercializing various aspects of their programs. These companies encompass the aerospace industry, a glass producing corporation, as well as a major medical university and a privately endowed foundation.

Question 11:

a. Does the NASA Joint Endeavor Agreement with McDonnell-Douglas preclude or in any way affect NASA's prerogative to do further work in continuous flow electrophoresis?

b. Do you believe that the terms of the Joint Endeavor Agreement which, in effect, penalize other users of continuous flow electrophoresis are the best way to promote progress in bioprocessing research?

Answer 11:

a. The NASA Joint Endeavor Agreement (JEA) with McDonnell-Douglas in no way precludes NASA's prerogative to do further work in continuous flow electrophoresis. This is explicitly stated in the JEA. In fact, NASA is actively developing new concepts for effectively utilizing microgravity to improve electrophoresis or to offer new separation concepts.

b. The terms of NASA's JEA with McDonnell-Douglas do not penalize other users of continuous flow electrophoresis. NASA is required by law to publish in the Commerce Business Daily, 30 days before finalizing, any JEA that is in negotiation and invites competitive proposals. The exclusivity clause in the JEA only prevents NASA from entering into a similar JEA with other commercial users that wish to use the same process. The MDAC JEA does not preclude other forms of electrokenetic separation from being pursued by those who wish to do so.

Question 12:

How does a Joint Endeavor Agreement affect the assignment of patent rights?

Answer 12:

Since no funds are exchanged in a JEA, the Government has no claims on patents developed in such an endeavor.

Question 13:

a. Please explain in more detail what you are going to do with the extra $2 million appropriated for FY 1984.

b. What are the FY 1985 funding implications if one or more centers are established in FY 1984?

Answer 13:

a. It is NASA's intention to use a portion of the additional $2 million to establish one or more centers for bioprocessing research. In addition, some of the $2.0 million will be used to develop new hardware to allow more microgravity experiments to be conducted on the Shuttle mid-deck. The mid-deck experiments will provide more low-cost research opportunities to the microgravity science community.

b. The university center, once established, will, of course, require continued support.

Question 14:

How can we promote greater interaction between NASA and other Federal agencies having needs and interests in materials processing?

Answer 14:

We have, in the past, maintained liaison with other Government agencies such as NIH, CDC, DOD, DOC, DOE, and NSF, as appropriate, to our various activities, and we will continue to interact with these agencies on a regular basis. Members of the working groups which have been established for the Materials Processing in Space Program also are in contact with many of these other agencies.

Question 15:

What differences do you see between the proposed NASA-funded university center and the highly successful National Science Foundation sponsored industry/academic centers?

Answer 15:

The major difference between the proposed NASA-funded university center and the NSF-sponsored industry/academic centers is that NASA must insist that the work actually sponsored by NASA is relevant to NASA's goals and objectives. NASA must be cautious not to sponsor work, however worthy, that is more appropriately sponsored by other Government agencies. Therefore, the emphasis in the NASA-sponsored center should be to focus on processes in which gravity is thought to play a pervasive role and can only be verified in space.

Question 16:

Do you see any potential for NASA to adopt patent rights agreements in manner similar to NIH?

Answer 16:

No potential is seen for adopting any patent rights agreements in compliance with Public Law 96-517 (35 U.S.C. 200 et seq.), dealing with the disposition of rights to inventions made under Government funding agreements with nonprofit organizations and small business firms.

Question 17:

There appears to be an overwhelming sentiment on the part of the scientific community that the "secrecy" surrounding the McDonnell-Douglas experiment does not promote a desirable level of free scientific exchange and, hence, maybe detrimental to the progress in their field.

a. Why has NASA apparently abandoned its traditional policy of free scientific exchange of data?

b. What can you do to disseminate the McDonnell-Douglas results in the near-term?

c. What will you do to prevent similar occurrences in the future?

Answer 17:

a. NASA has not abandoned its policy of free exchange of scientific data. However, a company investing its own money into an endeavor must be allowed to hold certain aspects of their venture as proprietary; otherwise, we could never attract any commercial endeavors. Data rights are part of the considerations negotiated in such a Joint Endeavor Agreement. In the case of the McDonnell-Douglas agreement, NASA agreed to provide a certain number of flights in exchange for the processing of a certain number of NASA-supplied samples. These samples were chosen to evaluate the effectiveness of doing electrophoresis in the microgravity environment. The results regarding the NASA-supplied samples are being analyzed and will be published in the open literature shortly.

b. In the near term, the McDonnell-Douglas continuous flow electrophoresis results will probably continue to be held as proprietary, and we will be unable to disseminate the data. The decision regarding dissemination of the data will have to be made by McDonnell-Douglas.

c. It is probable that similar instances of applied research of a proprietary nature will take place in the future and the free exchange of data which is typical of the basic research environment will not occur. As we proceed in commercialization of space, handling proprietary data may have to become a new way of doing business.

Mr. **Volkmer**. Thank you very much, Dr. Halpern.

In the name change, is that in effect at this present time—or are they microgravity——

Dr. **Halpern**. Science and Applications——

Mr. **Volkmer** [continuing]. Science and Applications Division?

Dr. **Halpern**. We're using it, Mr. Chairman, it has not been officially blessed by the Administrator at this point.

Mr. **Volkmer**. All right, so I guess we could use Material Processing in Space interchangeably——

Dr. **Halpern**. Yes, sir.

Mr. **Volkmer** [continuing]. For the purpose of this hearing so we all know what we're talking about. OK.

Now, we do have some microgravity or material processing activities planned for the spacelab program.

Dr. **Halpern**. Yes, sir.

Mr. **Volkmer**. Is that not correct?

Dr. **Halpern**. That's correct.

Mr. **Volkmer**. Now, what is the relationship between your division—your program and the spacelab operation? In relation to those programs?

Dr. **Halpern**. We think of the spacelab as being, in effect, our launch vehicle that takes us into space. It is my job to provide facilities for our research program, which are then given to the spacelab organization and it's their job to get those pieces of apparatus into the shuttle and actually get them flown for us. We work very closely with the division. As a matter of fact, at the present time, I still hold a dual job. I'm the Deputy Director of that division, as well as the Director of Materials Processing in Space. My Deputy's job will come to a conclusion immediately following the launching of spacelab I which is planned to be launched next month.

Mr. **Volkmer**. All right. For those materials processing applications that are going into this spacelab, are those budgeted to your division or spacelab?

Dr. **Halpern**. There are two types of apparatus currently. About 2 years ago, it was felt that the Spacelab Division had a stronger engineering capability than the Materials Processing in Space Division had at that time.

As a result, certain pieces of apparatus were made the responsibility of the Spacelab Division and appropriate funds transferred to that division to take care of that apparatus. In particular, those two pieces of apparatus consisted of a facility which will fly on spacelab III, known as the FES/VCG, which is a piece of apparatus designed to grow crystals in space; and the second piece of apparatus was the materials experiment accommodation unit, which is, in effect, a piece of equipment that supplies power cooling and so forth to the apparatus which I built. That is really the tie-in from an engineering standpoint.

We work, of course, very closely with the Spacelab Division and those pieces were built under the scientific direction of the Materials Processing in Space Division, although the engineering was done in the Spacelab Division.

Mr. **Volkmer**. I have a question in regard to the centers. As I read your statement, the proposal to first develop one on pharmaceuticals. The center's going to be developed on a—in a sphere of specific idea or technology? In other words, are we going to do one on crystals; are we going to do one on pharmaceuticals; are we going to have a center on metal alloys; are we going to just have one center that'll do all of these, look at everything, or, as you say, microgravity science?

Dr. **Halpern**. Well, your vision may extend further than mine, Mr. Chairman, and that may ultimately happen one day. The plan right now, however, is that in the immediate future, we would attempt to establish a center on bioprocessing research, including, of course, pharmaceuticals.

With that one idea in mind, there appears to be a great potential in that field for use of space and we would like to concentrate on that idea with one or more—ultimately, I don't know how many centers in that area will be established.

Beyond that point, university centers for research in other areas of materials sciences may some day come into being, but I have no immediate plans to establish such centers at this time.

Mr. **Volkmer**. All right.

Now, you have said that the future of NASA's program seems to place emphasis on flight experimentation to the use of the STS mid-deck facilities——

Dr. **Halpern**. Yes, sir.

Mr. **Volkmer** [continuing]. Is that correct?

Dr. **Halpern**. Yes, sir.

Mr. **Volkmer**. Yet, it seems that the NRC and SAB said that you should base your experiments on sound science done on Earth rather than existence of the flight opportunities.

How do we reconcile what you're doing with what was recommended?

Dr. **Halpern**. Well, I think we are following the recommendation. I hope very much that we can expand our Earth-based scientific research program—and I plan to do that.

At the same time, Mr. Chairman, the division has to have zero-g time in order to accomplish its research. On the ground, we can achieve upward of 4 seconds of zero-g time in any given instant of experimentation through the use of drop towers or drop tubes. We can get something on the order of 20 seconds worth of zero-g time if we use the KC-135 in a parabolic trajectory.

The other opportunity that's available to us, and we have used, are sounding rockets, where we can get maybe 5 minutes of zero-g exposure. What I'm trying to express is that in order to get any real duration of microgravity, we must go up into space and that's the only way our research program can come to fruition. So the two things are tied together.

Mr. **Volkmer**. Are you basically telling me, then, as I understand it as a layman, that we're limited in the amount of research that we can do in microgravity by the access to the space shuttle?

Dr. **Halpern**. That's correct, sir.

Mr. **Volkmer**. I think I've used up my 5 minutes this time.

Mr. Walker.

Mr. **Walker**. Thank you, Mr. Chairman.

Dr. Halpern, I'd like you just for a moment to tell us what the dreamers in your office think about where some of their experiments are going to take this country in the future. What are the potentials of the various kinds of things that you are engaged in in the pharmaceuticals, in crystal growth? What are the applications, and I'm particularly interested in what might be the commercial applications for the future?

Dr. HALPERN. I have to preface my speculations, however, by saying that before the dreamers take over the field, it's important to have a solid base from which to spring and that is the thrust that I hope to be able to point to in the near future.

Mr. WALKER. In order to get the resources, though, to give you that kind of base, we have to be able to tell the American people what it is we may get out of that base and to some extent, your dreamers are the ones who are going to give us the ability in the science to get that particular kind of—of substance for us to sell the American people.

Dr. HALPERN. Certainly, sir. I simply hope to preface my dreaming remarks.

Mr. WALKER. OK.

Dr. HALPERN [continuing]. With the fact that the dreams ultimately have to be based on something solid. Now, as far as dreams are concerned, there appear, at this point in time, to be two areas in particular that are susceptible for industrialization and those two areas, of course, are biological research, as well as semiconductor research.

The reason for that, of course, is simple: The cost of going into space is high, and so if you're talking about actually manufacturing materials or performing certain processes in space, the return on those processes has to also be high. In those two areas, we know that they are.

As far as—and I expect to see more work now that McDonnell Douglas has opened up the field and I hope that they become very successful in that field. There is a great deal of promise being shown.

One word that I'd like to throw in for the benefit of this committee, and I hope you will bear with me; I understand about the support and the great things that are going to be done which I very much believe in. The one word of caution that I would like to bring out is the fact that these things are not going to happen overnight. McDonnell Douglas, which at the present time is showing the way, estimates that it will be at least 10 years before there is any sort of positive cashflow into that company, so I hope that we don't expect these changes to occur tomorrow. It is unlikely that they will.

Many people have pointed out that typically it takes 10 to 15 years to go from an applied research project to an actual product that is marketable and I do not expect that we are going to see a great change in that time, perhaps a year or two, but not too many.

Some of the dreamers, of course, want to see large, long-duration facilities permanently up in space and there has been speculation as to the commercial use of these large facilities. Frankly, I think it's going to happen. I hope it happens shortly, but that's my wish. I think we will see things in space in this particular area that none of us had any idea of 5 years ago. About 10 years ago, somebody came out with a hula hoop and it was an overnight sensation and nobody had ever thought of it before. I expect that if you're talking about dreams in space, those are the kinds of things that will ultimately occur that none of us—well, I shouldn't say none of us, I don't know all of the people here, but that most scientists and engineers have no idea of.

I think the American industry is strong enough to be able to pick out those things that it sees as desirable or profitable and pick them up and tell us where they want to go.

Mr. **Walker**. Well, I guess what I had reference to, though, was I noticed in your—in your statement, you talked about the—perhaps the ability to produce new forms of glass in—in outer space. What—what commercial applications are you seeing for that kind of thing?

When you talk about the fact that semiconductor experimentation might result in products there; what would that mean in terms of, for instance, increased computer capacity and giving the United States an upgrade? When we talk about biological experimentation, the possible production of new pharmaceuticals, what kind of diseases might we hope to cure through those kinds of things? I mean, surely some of your people are thinking along those lines and I think it would be important to begin to define for people where that thinking is going.

Dr. **Halpern**. Let me try to answer that question, Mr. Walker. Certainly in the area of new kinds of glasses, there is great interest in trying to produce what are known as halide glasses. The reason for the desirability of these particular kinds of glasses is in the fiber optics industry and the ability to produce very thin transmission lines. We currently have repeaters for televisions, radio facilities and so forth. It is hoped if we can produce the kind of fiber optics that we're talking about, rather than have repeater stations every 30 to 50 miles in order to transmit communications, this would be perhaps on the order of hundreds of kilometers so that there would be a great increase in our ability to communicate, as well as a decrease in the cost of the communications.

As far as pharmaceuticals are concerned, there, of course, has been a great deal of research and tremendous interest, in cancer and there is some possibility that is being discussed—I don't want to mislead the committee and say a cure for cancer, but there certainly is biological research in certain monoclonal antibodies and some discussion ongoing of the possibility of production of these antibodies in a space environment.

There has been discussion of either a cure or perhaps a one-time antibody for diabetes. The research is ongoing in that area and this kind of potential has to have great impact on the American public, as well as on the world.

Mr. **Walker**. Thank you, Mr. Chairman, I've more than used my time.

Mr. **Volkmer**. I have a couple of other questions, Mr. Halpern. One, I'd like to get back a little bit to what we were exploring before on these centers and the utilization of the shuttle, et cetera.

As we look into the future, we're going to have a lot more shuttle flights than we presently have. We're going to have, then, more availability. Do we agree on that?

Dr. **Halpern**. Yes, sir, I certainly hope so.

Mr. VOLKMER. Three or four years from now, we'll have more availability than we presently have because undoubtedly we'll have more flights and there will be some availability on the mid-deck. What are we doing now to plan for those kinds of—to utilize that area—that space? 1986, 1987?

Dr. HALPERN. I certainly agree, Mr. Chairman, that the plan is for more shuttle flights and we hope to take advantage of those shuttle flights. We are doing two things. First of all, we have an active ongoing research program. I believe I point out in my testimony that one of the criteria for selection of a research program is the relevance of microgravity.

It is expected that our Earth research program will ultimately require the demonstration of the microgravity environment, which means going up into space. In particular, we look forward to the time when our research program moves from ground research to small-flight experimentation and then if it's profitable, or it's deemed profitable, into an industrialization process.

This is what I see as our normal path. There are experiments that are being considered right now and we are moving out to begin building the apparatus needed to fly them in the 1986, 1987, 1988 time periods.

Mr. VOLKMER. That's—I was curious as to whether or not—you know, we know there's going to be certain flights at certain times in the time period. Do we have experiments ongoing being prepared at this time that will utilize that—that flight time?

Dr. HALPERN. Absolutely. We have experimentation being prepared through the university research groups. We have experimentation being prepared through our NASA center, particularly in the areas of solidification work. We have experimentation being prepared for crystal growth and biologicals, and as I mentioned earlier, Mr. Chairman, we are working very heavily in the area of containerless processing, which we expect to open up next year but very clearly, that's something that will continue on into the future.

Mr. VOLKMER. In that regard, in continuation in the future, is there a chance that NASA in the material processing of microgravity science that NASA is going to be conducting the R&D to support on a continuing basis right down the line material processing in space industry?

Dr. HALPERN. I believe, Mr. Chairman, that NASA will not continue indefinitely in that role. It may take 5 years, it may take 10 years to get us to the point where we have a solid research base upon which industry can build. It has been NASA's posture in the past, and I assume that it would continue in the future, that once a particular technique has been demonstrated through the R&D base, NASA support for that particular area and goes into other areas of research.

I think perhaps the most clear example of that was in the communications field where NASA early on did the research necessary to demonstrate the communications satellites and then got out of the business when Comsat and the American industry came along. NASA has only recently gotten back into the business because it's been demonstrated that, in fact, there are new techniques, but they are such a complex and high-risk nature that it was not felt by industry that they could undertake that kind of research, and therefore came to the Government to assist in that regard.

Mr. VOLKMER. We came to realize that in the communications industry, the new techniques would be necessary, but the industry was not developing and therefore, it became NASA's job again——

Dr. HALPERN. Yes.

Mr. VOLKMER [continuing]. To do it. Well, we'll—I'm sure that we cannot foresee right now any milestones in the future as far as material processing. But we can say that—you know, in 1990, we're going to be only doing this much and 1995, we're going to be out of it. We're not at the point right now.

Dr. HALPERN. No, sir, we're not. I'm taking one day at a time and I look forward to the time when that will occur, but I don't think it's here yet.

Mr. VOLKMER. And nor are you in a position to be able to say when it will be.

Dr. HALPERN. No, sir, I'm not.

Mr. VOLKMER. All right.

Now, on the Joint Endeavor Agreements, there was one with GTI, right? They decided to terminate, as I understand it, because of lack of interest—they advertised and stuff and did not get the response. They plan to produce metal alloys under microgravity attractive to researchers in university and industry, as I understand.

Can you tell us what went wrong with it?

Dr. HALPERN. I will be glad to tell you what I know about it and what I've gotten from discussions with people at GTI.

Their perception of what went wrong was that they had a good idea whose time hadn't arrived. The GTI program involved building a facility into which samples could be placed from commercial customers. In order to pay for the cost of flights, as well as to return the GTI investment, the price per sample was higher than potential customers thought reasonable at the time. The base had not been established and in discussions with GTI personnel and former GTI personnel, every one of them still thinks it's a good idea and every one of them thinks that something of that kind will occur sometime in the future. They felt that they were too early.

Mr. VOLKMER. Now, what you're telling me, then, is that the failure—the problems that led to the failure are really specific to this one application, and not to—in general, to Joint Endeavor Agreements.

Dr. HALPERN. The problems that GTI had, Mr. Chairman, I believe, were specific to GTI.

Mr. VOLKMER. Yeah.

Dr. HALPERN. There is a generic problem that we are facing with the Joint Endeavor Agreement which is similar to the GTI problem, and that is that there is a reluctance on the part of some industrial organizations to invest at this time a great deal of money into space efforts because of the uncertainty of the return of that investment.

I got a little bit of an education from a vice president of one of these companies who informed me that many companies work on the second-best theory; that is to say they like to see company X take the first step in the investment risk and then companies A, B, C, et cetera will jump in after the investment has proven good and really make the money that the first company showed the way to make.

I think we're seeing a lot of that second step; people holding back waiting for somebody else to put the upfront money.

Mr. LUJAN. Would the gentleman yield?

Mr. VOLKMER. Yes, I——

Mr. LUJAN. Don't they have proprietary rights?

Dr. HALPERN. I'm sorry, sir?

Mr. LUJAN. Don't they get proprietary rights?

Dr. HALPERN. Yes, sir, they do.

Mr. LUJAN. The—how can—I don't understand how, then, why the reluctance because somebody else would jump in later on. They'd have the jump on anybody else if they——

Dr. HALPERN. Well, again, Mr. Lujan, if you'll allow me to speculate. Take the case of McDonnell Douglas Aerospace Corp. MDAC has invested a good bit of money. I have no idea of exactly how much, but certainly the equipment that they've built must have cost them quite a bit of money.

The electrophoresis process has been known for almost 90 years; it's not something new. MDAC took the first step of saying that they could build a piece of equipment to process a proprietary biological fluid in this apparatus and separate out something and ultimately make a great deal of money doing this. But it took a lot of guts and a lot of hard cash in order to take that step.

What I'm suggesting is that if they prove successful, you will see other pharmaceutical companies building electrophoresis equipment and flying it and producing some other kind of pharmaceutical product. Or you will see pharmaceutical companies looking at the electrophoretic process and making adjustments to the space work in order to do the same thing on the ground.

Mr. VOLKMER. Any further questions, I'll finish my questions?

Mr. LUJAN. Yes; I did. As a matter of fact, on this whole question of setting up universities as centers of excellence, that's in the 1984 budget. Are you thinking of several universities, one university, or different ones with different specialties? What is the thinking?

Dr. HALPERN. My thinking at this point, sir, is that there might be more than one. I believe I mentioned a short time ago that we will be sending out a—an announcement to universities that we are interested in establishing a bioprocessing research facility and it will depend, of course, on the amount of interest that is shown throughout the country.

Mr. LUJAN. Do you send it to all universities?

Dr. HALPERN. Yes, sir.

Mr. LUJAN. Yes.

Dr. HALPERN. I mentioned to Mr. Volkmer earlier that even before this announcement has been released, just on the basis of the appropriations bill that was published, I have received a great deal of interest already from universities.

Mr. LUJAN. What about industry sharing the—the university paying part of the cost, NASA paying part of the cost, industry sharing in it, although we may run into the same problem that you're talking about in relation to research?

Dr. **Halpern**. Well, several universities that have come to me already to express their interest have indicated that in preliminary discussions, they would expect exactly what you suggest.

Mr. **Lujan**. Because we could leverage some of those Federal funds.

Dr. **Halpern**. You will be talking with Dr. Flemings tomorrow and I believe he will tell you that same kind of story regarding the Materials Processing Center at MIT. NASA originally established it on a relatively small grant and Dr. Flemings will mention how that small grant has been leveraged, just as you suggest, through the university, but primarily through the industrial interest that has been expressed so that it has grown from a few hundred thousand dollars to several million dollars a year.

Mr. **Lujan**. We—the reason I asked you if you circulated to all universities to see what interest, we are rather sensitive about—and I'm not talking about the committee now, perhaps, as we represent different States would be more the reason for the concern that the same universities keep getting all of the research dollars and that's a concern. Should we be worried about that as far as this program is concerned or will there be some kind of an effort to—to see that various universities that have not previous—I don't mean that don't have a good research capability, of course, that's got to be number—No. 1, but we tend to look at the friends that we've dealt with before and rather ignore—ignore others.

Dr. **Halpern**. I believe you've partially answered your question. Excellence, I believe, ought to come first. I certainly understand what you're suggesting and the way I would hope to avoid the problem that you suggest is by establishing legitimate, realizable criteria for the selection of these universities which will be widely publicized so any university that believes it can meet the criteria, can propose.

The second step, of course, is to set up a review committee of competent biologists, medical people and so forth who have the knowledge in order to review the proposals and make that kind of a selection.

Mr. **Lujan**. I don't mean to make a welfare program for universities, you understand; it's simply that on the various committees that we sit on, we notice, you know, the same universities doing all of the research.

We'll leave that for a while. I've raised——[Laughter.]

Mr. **Lujan**. I've raised the concern, and I realize it's a tough question to answer, but it's—it's—it—there can be some sensitivity to that problem.

The final question is there's so little time for experiments on the shuttle, even though, you know, you—a particular experiment may get some time on it. What's your thinking to answer that with a space platform or, you know, station of some kind?

Dr. **Halpern**. The time that we get on the shuttle currently is measured in the order of days of exposure to zero-g or microgravity. That ultimately may prove to be too short, but right now, we are in the situation where an exposure of a day is several orders of magnitude more than we have had in the past and so it is my plan to take one step at a time.

I have had nothing yet proposed to me that requires durations longer than the shuttle is able to accommodate.

Mr. **Lujan**. Well, electrophoresis, to get into production. Now, if we're talking about just the research part of it, you're correct, but all of the research in the world, you know, unless we put it into practical applications—I suppose the need is there right now for some sort of a platform if electrophoresis has been—has been—oh, reached success and we have the equipment and it needs to be refined or whatever needs to be done.

We need a place to—and I'm sorry that that's the only example really that——

Dr. **Halpern**. I think, sir, that emphasizes the point I was trying to make which was that even in the case of electrophoresis, their mode of procedure was to take the middeck first on the shuttle, to move from the middeck into the orbiter bay, from the orbiter bay out to a platform and then perhaps from a platform to a more permanent kind of factory in space.

They foresee the need for the long duration, large pieces of equipment. They have an end product in mind. What I was trying to express was the fact that at this point in time, they are unique in that end process requiring long duration.

I certainly could speculate on other products, but none of them——

Mr. **Lujan**. Are you saying we can't build a platform for just one product, that we need to——

Dr. **Halpern**. No, no, sir, I wasn't saying that. What I was trying to express was the fact that at this point in time, the MDAC plan is the only one that is known to require that sort of thing. On the other hand, I can visualize a platform or a space station which would handle many different kinds of processes and products.

Mr. **Lujan**. Thank you, Mr. Chairman.

Mr. **Volkmer**. I still have a couple more questions, Dr. Halpern. One is that there is additional $2 million put into the appropriation above you request, or the request of the agency for the division. How do you plan to use that extra $2 million?

Dr. **Halpern**. Mr. Chairman, our operating plan for 1984, of course, has not been completed yet, but I can certainly tell you the elements of how we plan to use the $2 million. We certainly expect to spend a portion of that money on the university centers that we've been discussing here. A portion of that money will be put into the start of new apparatus, the small, low-cost, middeck kind of experimentation that I was talking about and I expect to put a further portion of that money into additional research programs which ultimately, I hope, will lead to applications of one type or another.

I plan to issue, within the next 3 to 4 months, a "Dear Colleague" letter, not only to universities, but perhaps also to some industrial organizations, looking for new kinds of experimentation which we can properly undertake.

Mr. **Volkmer**. Then, the—basically, when your're saying there, "research," our witness that will follow you, in his statement, speaks of tension in the material processing program between those who desire immediate achievement of commercially important products and those who want to do research, basically basic research. Now, is this tension healthy to the program?

Dr. **Halpern**. Well——

Mr. **Volkmer**. Or does it exist, in your viewpoint?

Dr. **Halpern**. I'd like to have Dr. Rindone answer that question, but I'll certainly try to express my thoughts on the subject.

I suppose there is always some kind of a pull and tug between pure science and applied science. And if that's what Guy is talking about, I certainly agree that there is some of that. The pull and tug, of course, comes in competition for resources.

I think the only thing I can say, Mr. Chairman, is that I will do my best to keep that at a minimum. I do believe that applied research has to be built on solid basic research before it comes to fruition and in that regard, I think we do have a quality, maturing research base upon which to build applications. I have not seen anything that I would call counterproductive at this point in time and as I said, I will do my best to try to avoid that in the future.

Mr. **Volkmer**. Any further questions?

Thank you very much, I have no further questions. If we do have, I will go through some things here, we will submit them in writing and you can submit your answers for the record in writing.

Dr. **Halpern**. Thank you very much, Mr. Chairman.

Mr. **Volkmer**. Thank you very much for being here this morning; you've been very helpful and look forward, as I said in my opening statement, to working with you for a more productive, if at all possible, microgravity science applications program.

Dr. **Halpern**. Thank you again, sir, I appreciated the opportunity to appear before the subcommittee.

Mr. **Volkmer**. Thank you.

Our next witness is Dr. Guy Rindone, University Space Research Association, Pennsylvania State University.

Mr. **Lujan**. Mr. Chairman, before we proceed, I'd ask to include this in the record immediately following——

Mr. **Volkmer**. You would. All right, at this time, his statement—Congressman Lujan's statement will be made a part of the record and will appear right after my opening statement in the record.

Mr. **Lujan**. Understand, Mr. Chairman, that I'm going to have to leave. I have to go over to the Rules Committee on coal slurry pipeline, so——

Mr. **Volkmer**. OK.

Mr. **Lujan** [continuing]. If you'll excuse me.

Mr. **Volkmer**. All right. Thank you very much.

Dr. Rindone, your statement, too, will be made a part of the record and will appear in the record in full. You may either review the statement in total or summarize it, however you so desire.

STATEMENT OF DR. GUY RINDONE, UNIVERSITIES SPACE RESEARCH ASSOCIATION, PENNSYLVANIA STATE UNIVERSITY

Dr. **Rindone**. Thank you, Mr. Chairman. I'm very happy to be here before this committee to tell you of some of the activities in which we have been involved in USRA and I'd like to emphasize some of the points which were in my written statement.

First of all, I would like to inform those who might not be aware of the fact that the Universities Space Research Association was established by the National Academy of Sciences in 1969 as a means by which universities and other research organizations could cooperate with one another, with the U.S. Government, and with other organizations toward the development of knowledge associated with space science and technology.

I personally have been involved in the MPS program for a period of about 11 years; first as a member of a particular committee established by NASA through USRA and then, more recently, as a coordinator of some of the working groups that NASA has established through USRA in order to promote continuity and good scientific thrust in the materials program.

I've been very enthusiastic about the MPS program during this whole time because I feel that space offers tremendous opportunities for those who are engaged in the materials field and there are several reasons for this. The main features of space that we can point out as being important are the fact that we have very low gravity. There is a vaccum of unlimited pumping capacity. We can make studies using unfiltered radiation which we don't have on Earth and the unlimited dimensions of space make it possible to perform some operations which you couldn't perform on Earth.

Now, of these features, the single most important one, I believe, is the use of reduced gravity environment or the microgravity environment. I'm sorry to say, however, that my enthusiasm is not shared by the majority of the materials science community. There's a good reason for this. The reason—the main reason—is that the potential for space processing in the materials area or space research are not as obvious to the materials person as would be the potentials for space research to the astronomer, who'd have the use of a space telescope, for example, where he could observe distant planets and galaxies without the interference of the atmosphere.

So, we need to expend greater efforts to inform the scientific community of the potentials for space exploration in the materials field. A great effort has been expended so far but more effort is needed. But what I think we have to emphasize is that there are scientific phenomena which can be studied in the space environment which cannot be studied on Earth, which will lead to a better understanding of scientific phenomena, which in turn will lead to a development of new materials and improved processes which can be carried on in Earth's gravity fields.

In other words, we must be looking at those areas where we can learn something in a space environment which is going to improve our materials field on Earth. I think this is a very important aspect which has not received as much attention as it should.

Now, in the beginning, there were a number of experiments which were performed—in order to produce articles in space—for the purpose of seeing what could be done. Now, consequently, the direction of some of this work didn't have a good scientific base and consequently, a committee of the National Academy of Sciences in 1978 pointed out that it's extremely important that one establish a good scientific base for the performance of space experiments in space processing work.

Now, the efforts to involve the universities—the scientific community, both university and industry, have been held back by—for several factors. One—one of which, first of all, is that the timelag between the conception of an experiment and the actual flight experiment has been very long; we're talking of perhaps 8 years. Now, this timeframe is very long in contrast to the research efforts of university personnel, particularly.

If you have graduate students who are working on a doctoral program—a doctoral program is usually completed in 4 or 5 years—the research may be taking 3 years. Now, an investigator or a faculty member submitting proposals, then, cannot visualize the completion of a particular research effort during the term of a particular graduate student.

Now, hopefully this situation will be improved because of the increased availability of shuttle flights—now that the shuttle is operational—so that perhaps this timelag can be cut down. But there is another reason, and that is the funding level for research in the materials area has been much too low considering the magnitude of the materials field.

One way to interest the scientific community into a—looking into—a program is to make available funding on such a scale that a faculty member, for example, at a university, would be interested in submitting a proposal in a materials area which is microgravity related, whereas previous to that, he may not even have thought of using space as a laboratory, but the fact is that every faculty member is trying to support his research, and support graduate students, and consequently, they are looking for sources of funding.

When it becomes known that NASA has moneys which are available for materials research, which is related to the space environment, then more investigators will look into the program and see if there is some basis for using the space environment for their research.

Now, as far as industry is concerned, we certainly need a greater participation of industry in the program. I think it's a mistake, however, at this stage, to offer the plum that industry is going to make something up in space better than they can make it here on Earth. Now, this may be true in some instances and we've seen evidence of this in the biological field, certainly, but it is not clear to industry personnel that their particular product is going to be made up there better or in an economically feasible way.

So what we have to do is to inform industry of the potentials of space research and space processing—materials processing research—because space offers a unique laboratory for understanding and improving materials, whether they're made on Earth, or whether they're made in space, but certainly the more direct benefit will be in improving materials made—made on Earth.

We need industry involvement in other ways. There will be in the future space stations built on the Moon, or on planets, or orbiting and we are going to need the expertise of industry personnel in building these materials, and so we have to know—we have to have experiments designed which will enable us to learn how do we make metals in the space environment; how do we make glass, ceramics, or plastic materials? Ordinary materials? We have no experience. What are the difficulties we are going to run into if we try to melt a metal or to fabricate a metal in space?

We need to get industry involved in a program where they will lend their expertise that they have--in making their particular materials—to the space program to help us determine how we are going to do this in a space environment.

But also, we need industry's help in determining what can we use in terms of the raw materials that are available in space, the raw materials of the Moon, the raw materials of planets, asteroids, but in addition to that, the raw materials which are available from manmade debris which is orbiting space. We have a wealth of metals and materials in space which are doing no good at the present time, which could serve as a very good resource for building some kind of a space station on the Moon or orbiting.

We need the expertise of the people in industry to teach us, to help us with the technology of how do we extract these materials; once we have them extracted, how do we use them, how do we prepare them, and how do we fabricate them?

There's another area that we need a greater thrust in. I think a good effort has been made in getting cooperation in coordinating efforts with foreign agencies involved in the space program. There's a—good coordination has been started with ESA, for example, the European Space Agency, where scientists meet with one another, the Europeans and American scientists at meetings, at working groups, at symposia, exchange ideas, but in addition to exchanging ideas, they also have the possibility of exchanging the use of facilities.

There's some very fine equipment being built in Europe. As you know, the spacelab—which is going up in a short time—was built in Europe by the Europeans, and there are individual investigators that have facilities which would be very useful in our program. By continuing to coordinate and increasing our efforts to coordinate the programs in NASA and the programs with these other agencies, I think we will find a more rapid advancement in the materials program and perhaps in—at a lower cost, but also, we will have the generation of more ideas for what can be done in the materials area in space.

So, to summarize our feelings in regard to the materials program in space, I think we have to look for a greater effort to involve the scientific community, both the industrial and university in the program, and one way to do this is by an increased funding program for basic research which is microgravity related.

I think we have to increase our involvement of industry in the program, not so much from the idea that they're going to commercialize a particular product—eventually we hope this will happen—but from the idea that industry will gain significantly from the knowledge to be gained by their research in the space environment, performing experiments which they could not at all perform in a gravity field.

Then I think we have to emphasize the cooperation between industry and university scientists and NASA personnel in looking at the resources which are available in space for the materials field so that each may lend its expertise to the proper utilization of these materials.

Lastly, I feel that cooperation with foreign agencies such as ESA is extremely important for progress to be made effectively, efficiently, and with good scientific thrust in the materials area.

Thank you, Mr. Chairman.

[The prepared statement, plus answers to questions asked of Dr. Rindone, follow:]

PREPARED STATEMENT OF DR. GUY E. RINDONE

Introduction

Mr. Chairman and members of the Committee, I am Professor Emeritus in the Materials Science Department of the Pennsylvania State University. I served as Professor of Ceramic Science and Chairman of the Ceramic Science and Engineering section of the department from 1969 until I retired in 1980. I have been an active member and past officer in various capacities of the American Ceramic Society and the International Commission on Glass. My resume is attached.

I have been involved in NASA's Materials Processing in Space program since 1973, serving on committees and working groups in the area of glass and ceramics. In 1980 I was asked by the Universities Space Research Association (USRA) to direct a program under contract with NASA aimed at helping NASA coordinate activities over the entire MPS program.

The Universities Space Research Association (USRA) is a private non-profit corporation that was organized in 1969 by the National Academy of Sciences. Upon incorporation, authority for the association was vested in a consortium of universities. The consortium now numbers fifty-four members, listed and shown on the map below.

USRA is chartered to provide a means through which universities and other research organizations may cooperate with one another, with the government of the United States, and with other organizations, toward the development of knowledge associated with space science and technology. USRA is further chartered to acquire, plan, construct, and operate laboratories and other facilities for research, development, and education associated with space science and technology.

- Alaska, University of
- Arizona State University
- Arizona, University of
- Boston College
- Brown University
- California, University of (Berkeley)
- California, University of (Los Angeles)
- California, University of (San Diego)
- Case Western Reserve University
- Chicago, University of
- Cornell University
- Denver, University of
- Georgetown University
- Georgia Institute of Technology
- Harvard University
- Hawaii, University of
- Houston, University of
- Illinois, University of (Urbana)
- Indiana University
- Johns Hopkins University
- Kansas, University of
- Lehigh University
- Louisiana State University (Baton Rouge)
- Maryland, University of (College Park)
- Massachusetts Institute of Technology
- Michigan, University of (Ann Arbor)
- Minnesota, University of (Minneapolis)
- New Hampshire, University of
- New York, State University of (Buffalo)
- New York, State University of (Stony Brook)
- New York University
- Northwestern University
- Ohio State University
- Old Dominion University
- Pennsylvania State University
- Pittsburgh, University of
- Princeton University
- Purdue University
- Rensselaer Polytechnic Institute
- Rice University
- Rockefeller University
- Stanford University
- Tel Aviv University
- Texas A & M University
- Texas, University of (Austin)
- Texas, University of (Dallas)
- Toronto, University of
- Virginia Polytechnic Institute and State University
- Virginia, University of
- Washington, University of
- Washington University (St. Louis)
- William and Mary, College of
- Wisconsin, University of (Madison)
- Yale University

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Institutes and Programs of USRA

In fulfilling its objectives, USRA operates three institutes, participates with NASA in an institute, and maintains two other major programs:

1. The Lunar and Planetary Institute (LPI) in Houston, which has been a focal point since 1969 for university research investigators in lunar and planetary sciences and related fields.

2. The Institute for Computer Applications in Science and Engineering (ICASE), where interactions are promoted between NASA and university scientists in the field of applied mathematics, numerical analysis and applied computer science. ICASE is located at the NASA/Langley Research Center in Hampton, Virginia.

3. The Research Institute for Advanced Computer Science (RIACS), which is located at the Ames Research Center, California. RIACS is chartered to undertake computer science investigations of first priority to NASA, leading to significant advancements in capabilities for large scale computational physics, expert systems technology for space and ground applications, control theory, and the life sciences.

4. The USRA Division of Space Biomedicine (DSB) participates in NASA's Space Biomedical Research Institute (SBRI), which is located at the NASA/Johnson Space Center. The SBRI focuses on those biomedical problems that are of concern to the health or effectiveness of the astronauts. The charter for the SBRI calls for the DSB to serve as an interface between the institute and the international community of researchers in universities, medical schools, private laboratories, and commercial organizations.

5. The USRA Atmospheric Processes program was established in 1976. The program provides visiting scientists in the atmospheric sciences to the NASA/Marshall Space Flight Center and the NASA/Goddard Space Flight Center. In addition the program carries out special studies and tasks both directly and in conjunction with university scientists.

6. The USRA Materials Processing in Space (MPS) program was established in 1971 to support the NASA/Marshall Space Flight Center. In 1981 the program was augmented to provide assistance to NASA Headquarters. The activities of the MPS program are described in the section that follows.

USRA's Materials Processing in Space Program

The first thrust of USRA in the MPS program started in 1971, under the direction of Dr. Henry Leidheiser of Lehigh University, to assist the MSFC in its activities. These were to form consultative committees and organize workshops to appraise the state-of-the-art, determine the role of microgravity in materials processing, and provide critical reviews of the ongoing programs. In addition, bibliographies have been compiled and visiting scientists have been provided to Marshall. The program continues under Dr. Leidheiser's direction, and most recently, visiting scientists at MSFC have conducted research on electrophoresis, biochemical separations, solidification processes under low gravity conditions, glasses and ceramics, and mercury cadmium telluride crystals.

At the outset of USRA's involvement in the MPS program its efforts were directed towards assisting MSFC. The original direction was to determine whether space environment would provide a means of processing materials which could not otherwise be made on earth or which could be improved by making them in space. This led to a strong technological emphasis in the MPS program. It became apparent that an important aspect of the program was being overlooked - that is, the opportunities space offers to perform scientific experiments which could lead to information that would improve materials processing on earth and perhaps also lead to the development of new materials with improved or unusual properties. The report of the committee on Scientific and Technical Aspects of Materials Processing in Space (The STAMPS Committee report - 1978), clearly made this point, and stressed the requirement that, "...problems proposed for investigation in space have from the outset a sound base in terrestrial science or technology and that the proposed experiments address scientific or technical problems and are not motivated primarily to take advantage of flight opportunities or capabilities of space facilities."

Since 1978 a strong science based research orientation has been given to the MPS program, first under the leadership of Dr. John Carruthers, and then under Dr. Louis Testardi. We are encouraged that the new director of the Microgravity Science Program at NASA, Mr. Richard E. Halpern, is determined to re-emphasize the scientific nature of the NASA effort and to address some of the operational problems that have slowed progress in the program.

Activities in the research aspects of the MPS program have expanded, not only at Marshall where the MPS program had been largely concentrated but at other NASA centers including the Jet Propulsion Laboratory (JPL), NASA's Lewis Research Center, Johnson Space Center, and the Ames Laboratory. In 1981, NASA asked USRA to organize and coordinate the functions of MPS working groups whose activities would encompass the whole program in addition to those at MSFC. In addition, USRA assumed the task of encouraging the scientific community to become more involved in the MPS program so that the direction of its activities could be assured of proceeding at the highest scientific level.

USRA has the responsibility of assisting NASA to identify new research areas and concepts, advanced technology needs, requirements for advanced flight hardware, and requirements for advanced microgravity facilities. The means to accomplish these responsibilities are by organizing, coordinating, and sponsoring working groups of experts, on-going seminars, especially at technical meetings of professional societies, and workshops. In addition, contacts are to be established with foreign organizations such as the European Space Agency (ESA) to promote cooperation in MPS activities, and with industry in order to generate an interest in exploring the benefits of materials processing research in space.

Science working groups (SWGs) have been formed or reorganized, the purpose of which are to provide interaction between NASA-funded investigators, scientists, and engineers from universities, industry and government labs, flight hardware contractors and NASA personnel. The SWGs cover the following areas:

- Bioprocessing
- Combustion Sciences
- Containerless Processing: Acoustic, Electromagnetic, Electric Field
- Fluids and Transport Phenomena
- Solidification processes: Float Zone Processing, Metals & Alloys, Electronic Materials

Smaller discipline groups (DWGs) may be formed from time to time. One such group on glasses and ceramics has been functioning since 1972. The membership is drawn from among internationally recognized scientists in universities and industry. Among the functions of the DWGs is to generate and suggest areas of study so as to insure that NASA is working in identified areas of scientific need. In addition they are to foster better communication with the scientific community on both a national and international basis.

Recent Activities

An outline summarizing the activities in the MPS program since 1981 in support of NASA Headquarters is attached. It is noteworthy to mention several activities in greater detail.

Since the reorganization of existing working groups and the formation of new ones, there have been one or more meetings each year in which there has been interaction among NASA personnel, investigators, scientists from universities, industries, and government laboratories, and hardware contractors. The activities of the Bioprocessing SWG have centered around the electrophoresis experiments being carried out on shuttle flights. The Containerless Processing SWG has been planning experiments to be run in the mid-flight-deck region of the shuttle in order to test an acoustic positioning device while melting glasses. The Glass and Ceramic DWG has assisted in the planning of experiments being carried out in shuttle flights involving glass formation and bubble motion. The Solidification SWG has been discussing current experiments involving drop tower facilities and KC-135 aircraft flights in preparation for future shuttle flights. The Float Zone SWG has been involved with a bread-board experiment system for producing high purity silicon. The Combustion Science SWG has been designing experiments to study flammability, particle combustion and droplet burning in low gravity.

During the past year an agreement has been made with the European Space Agency (ESA) to provide liaison between NASA's working groups and ESA's working groups. Representatives of ESA and NASA have been designated and have attended each other's meetings. There has also been activity in coordinating efforts to share experimental facilities and to promote joint ventures between ESA and NASA principal investigators.

Formal and informal contacts with industry and scientific personnel at technical meetings continue in order to get greater involvement in NASA's MPS program.

Status of NASA's MPS Program

From the perspective of the university space research community, NASA's MPS program is making progress, though not as rapidly as we would like. Since 1978 there has been a strong emphasis in the program on understanding the basic science involved in processing materials in low gravity. It is essential that this emphasis remains and that the program continues to be undergirded by ground based microgravity-related research activities.

We believe that progress in the program has been slowed primarily for the following reasons:

1. Because of the delay in making the shuttle operational, there have really been very few flight opportunities in recent years. From a university point-of-view, an optimum program would involve an interplay between ground based research and flight experiments which could be accomplished in a time frame commensurate with or shorter than the time to complete a doctoral program. At the moment there is a 6 to 8 year lag from the initiation of an investigation to actual flight. Graduate students in the materials sciences normally complete their doctoral programs in 4 to 5 years.

2. When you consider the wide range of disciplines involved in the program, the funding level for research, hardware development, and PI support has been quite modest. In FY 1983, $11.4 M in research funding was spread over the disciplines of containerless processing, bioprocessing, crystal growth, combustion, solidification, fluids, etc. Hardware development and PI support amounted only to $8M.

3. We believe that the potential for microgravity research and processing in the materials area is great. However, the potential is not as immediately obvious to the materials scientist as is the potential of the space telescope to the astronomer, for example. This fact, coupled with weak funding and limited flight opportunities has meant that interest in the MPS program by the scientific community has been slow to develop.

Future Directions of the MPS Program

Since the inception of the MPS program there has been a tension between those who desire the immediate achievement of commercially important products and those who wish to conduct investigations to elucidate the potentials and characteristics of space processing research. The joint endeavor agreements provide mechanisms for industries to pursue commercially viable space processes. A more aggressive, better funded, research program is needed to complement the commercial effort one which would encourage a larger number of excellent scientists to study, define, and characterize materials and phenomena related to materials through space processing research.

Funding for ground based microgravity-related research should be increased and the grant period offered for three years in order to assure prospective investigators that there will be a continuity of support of satisfactory completion of the study. Those studies which show promise for continuation under conditions during space flight would be clearly identifiable within this period and should be actively and rapidly pursued.

Concurrently, those proposals which are deemed to be excellent candidates for near-term flight experiments should be allocated adequate funds to provide the flight hardware required for the investigation. The investigators themselves should assume a major portion of the responsibility for procuring the apparatus required, with the advice of NASA personnel concerning flight requirements.

It will be unfortunate if the industrial interest in the Materials Processing in Space program continues to be limited only to joint endeavor agreements. We see three reasons why efforts should be increased to get greater involvement in the MPS research program by industry:

1. While it may not be evident or even possible to manufacture some materials better in a microgravity environment, studies can be made of certain scientific phenomena under microgravity conditions that cannot be made on earth. Such studies may well lead to a better understanding of the material under study and, hence, to improvement of the materials properties and/or processing when manufactured on earth.

2. The utilization of space in the future requires the manufacture of bulk materials in situ, whether in a space station, on the moon, or on a planet. Industry must work hand in hand with NASA scientists to assure that the best technology is utilized in learning how to process normal, every day materials in a microgravity environment. We need to know how to make metal, glass, plastic and ceramic materials in space. What are the unforseen problems?

3. The potential use of material from the moon, asteroids, or other bodies in the solar system as well as man-made space debris as raw materials for the manufacture of space stations, lunar buildings, etc., will have to be explored utilizing the expertise of industry in collaboration with materials scientists, planetary scientists, and astronomers.

Finally, we believe that efforts should be continued and expanded to cooperate with foreign agencies involved in microgravity studies of materials as has been initiated with ESA. The sharing of ideas and facilities together with joint projects will lead to more rapid advancements and at lower over-all costs.

Comments on Committee Recommendations

USRA has in the past recommended that NASA establish an institute in materials processing in space. We have held, however, that the principal focus of the institute should be on understanding phenomena rather than on the development of new products. Despite the apparent success of the McDonald Douglass/Johnson and Johnson electrophoresis unit on the Space Shuttle, we still believe it is premature to focus on products. If a research center is established to conduct research in this area, it should emphasize separation and purification processes rather than the product pharmaceuticals. USRA has supported such work by providing visiting scientists to the NASA/Marshall Space Flight Center, where research is being carried out on electrophoresis and the two-phase partition separation of biologicals.

We support the idea of involving more industrial scientists in the MPS program, and research funding for cooperative efforts between university scientists who have been involved in NASA's MPS program and industrial scientists who have not been involved in the program could be very effective. We do not believe, however, that such cooperative research efforts should necessarily be tied to commercial applications of space processing. We continue to believe it is more likely that industry will benefit from the use of the space environment to better understand materials and processes, and therefore to improve terrestrial processes.

SUMMARY OF USRA ACTIVITIES IN THE MATERIALS PROCESSING IN SPACE PROGRAM

UNDER CONTRACT NASW 3495

G. E. Rindone, USRA Director
June 1983

I. Science Working Group Meetings

A. Bioprocessing SWG established October 1981 - Paul Todd (Penn State) Chairman
Oct 12-13, 1981 - Wash. D.C., 18 participants
June 6-8, 1982 - Wash. D.C., 22 participants
Oct 24-26, 1982 - Wash. D.C., 24 participants
May 2-3, 1983 - Tucson, AZ, 18 participants

B. Containerless Processing SWG - Robert Doremus (R.P.I.) Chairman
March 26, 1981 - Arlington, VA, 20 participants
Aug 14, 1981 - Subgroup Mid Flight Deck - Wash. D.C., 14 participants
Dec 10, 1981 - Subgroup Mid Flight Deck - JPL, Pasadena, CA, 23 participants
June 14-15, 1982 - Subgroup Mid Flight Deck - JPL, Pasadena, CA, 10 participant
Sept 2-3, 1982 - Subgroup Mid Flight Deck - JPL, Pasadena, CA
Oct 21-22, 1982 - Alexandria, VA, 56 participants
Apr 20, 1983 - Subgroup Mid Flight Deck, 10 participants

C. Float Zone SWG - E. L. Kern (Consultant) Chairman
Sept 22, 1981 - Workshop, Marshall Space Flight Ctr., 39 participants
Feb 23, 1982 - Tempe, AZ, 18 participants
March 22-23, 1983 - Huntsville, AL, 31 participants

D. Solidification SWG established April 1982, Angus Hellawell (Mich Tech) Chairman
June 2, 1982 - Organizational Mtg., MIT, Cambridge, MA, 14 participants
Aug 24-26, 1982 - Wash. D.C., 33 participants
March 8, 1983 - Atlanta, GA, 15 participants
May 16-17, 1983 - Huntsville, AL, 40 participants

E. Fluids and Transport Processes SWG - Dudley Saville (Princeton) Chairman
Inactive

F. Science Working Group Chairmen's Meeting
April 15, 1982 - NASA Headquarters, Wash. D.C., 13 participants

II. Meetings with European MPS Personnel
March 29, 1982 - ESA, Paris (Malmejac, Huth, Pesenti, Rindone, Uhlmann)
May 3, 1982 - Cinn., OH (ACerS) Prof. Zarzycki (ESA) & Glass & Ceramic DWG
July 7-8, 1982 - Montpellier with ESA (Malmejac, Huth) Germany (Frischat, Bruckner), France (Zarzycki) and Glass & Ceramic DWG
Dec 14-16, 1982 - Paris with CNRS Working Group (A. Hellawell - Solidification SWG Chairman)
Feb 17-18, 1983 - Hallandale, FL with ESA Representative Zarzycki and Glass & Cer DWG

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III. Symposia at Technical Meetings

Nov 16-19, 1981 -- Materials Research Society Annual Meeting, Boston
May 4, 1982 - American Ceramic Soc. (Nat. Inst. Ceramic Engrs_NICE), Cinn., O
July 7, 1982, - 5th Intern. Conf. on the Physics of Non-Crystalline Solids, Montpellier, France
Apr 5-8, 1983 - "Materials Science Under Microgravity" Sponsored by ESA & Polytechnical University of Madrid, COSPAR & ELGRA

IV. Publications

Materials Processing in the Reduced Gravity Environment of Space
G. E. Rindone, Ed. Proceedings of the Materials Research Society Annual Meeting Vol 9, Elsevier Science Publisher, 676 pp (1982)

V. Consulting Scientists

Dr. Klaus Bachmann - North Carolina State University
"Study of Potential Research Studies Benefitting from Microgravity Experiments", September 1, 1981 - August 31, 1982

Prof. Robert J. Bayuzick - Vanderbilt University
"Summer Study on Nb-Ge"
June 1, 1982

Prof. Alan A. Johnson - University of Louisville
"Summer Study of Drop Tower Specimens of Au-Si Alloys"
June 1, 1982

Prof. Simon Ostrach - Case Western Reserve University
"Summer Study of Oscillatory Phenomena in Surface Tension Driven Flows"
June 1, 1982

VI. Industry Contacts - Formal Presentations

Aug 12, 1981 - Owens Illinois (N. J. Kreidl)
Aug. 13, 1981 - Corning Glass Co. (N. J. Kreidl)
Dec 4, 1981 - Brockway Glass Co. (G. E. Rindone)

VII. Future Meetings

Summer 1983 - SWG Chairmen at NASA Headquarters
July 8-9, 1983 - ESA Glass Working Group with Glass & Cer. DWG Hamburg, Germany (13th Internat. Congress on Glass)
October 1983 - Bioprocessing SWG, Bethesda, MD

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GUY E. RINDONE

Birth Date:
August 11, 1922, Buffalo, New York

Professor Emeritus of Ceramic Science and Engineering
Professor of Ceramic Science and Engineering
Chairman, Ceramic Science and Engineering Section, Materials Science and Engineering Department (1969-1980).

Status:
Regular tenure member and senior member of the Graduate Faculty

Educational Background:
B.S. in Glass Technology, Alfred University, 1943
M.S. in Ceramics, The Pennsylvania State University, 1946
Ph.D. in Ceramics, The Pennsylvania State University, 1948

Positions:

Graduate Asst. in Glass Science, Inc.	PSU, 1945-47
Research Asst. in Ceramics	PSU, 1947-49
Assistant Professor of Ceramics	PSU, 1949-61
Associate Professor of Ceramics Science	PSU, 1961-68
Professor of Ceramic Science and Engineering	PSU, 1968-80
Emeritus Professor of Ceramic Science and Engineering	1980-

Other Professional Experience:
Chemist, Linde Air Products Research Laboratory, 1942
Glass Technologist, Sylvania Electric Products, Inc. 1943-45

Membership and Activities in Professional Organizations:
1. American Ceramic Society
   a) Chairman Glass Division, 1960-61
   b) Vice-Chairman Glass Division, 1959-60
   c) Co-Chairman Symposium on Nucleation and Crystallization in Glasses, Toronto, 1961
   d) Steering Committee, Glass Division, current
   e) Trustee, Glass Division, 1971-74
2. International Commission of Glass
   a) Chairman, Technical Program, VI International Congress on Glass, Washington, DC 1962
   b) American Ceramic Society Delegate to ICG Council 1971 - present
3. Keramos Professional Ceramic Engineering Fraternity
   National President 1972-74
4. Society of Glass Technology, England, Amer. Treasurer 1979-present
5. Pennsylvania Ceramics Association, Counselor, Sec-Treas., Director
6. American Association for the Advancement of Science
7. Vice Pres. American Ceramic Society 1977-78

Published Articles: 71
See separate sheets

Books:
Editor and Co-editor of 5. (see separate sheets)

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Patents:
U.S. 11 (See separate sheets)
Foreign 4

Membership and Offices in Honorary Societies:

1. Sigma Xi - Secretary, Penn State Chapter 1978, President 1980
2. Phi Lambda Upsilon
3. Keramos - National Secretary, 1968-70, Vice Pres. 1970-73 President 1972-74
4. Sigma Tau
5. Tau Beta Pi

Awards and Honors:

1. Fellow American Ceramic Society, 1961
2. Frank Forrest Award for Outstanding Publications, 1963
3. Fellow Society of Glass Technology, 1975
4. Greaves Walker Roll of Honor, 1983

Consulting:

Consult for industries involved in electronics and electrical properties, electroluminescence and lighting, glass-metal combinations, optical properties, and glass-melting and forming operations.

Universities Space Research Association, Committee of Production of Glass in Space. Consultant to NASA 1972 -present

Air Force Office Scientific Research Chemistry Evaluation Panel 1976-1980

Participation in Professional Meetings and Symposia of Special Significance:

1. International Congress on Glass: Paris (1956), Washington (1962), Brussels (1965), Paris (1971), Japan (1974), Prague (1977), USA (1980), FRG (1983)
2. International Symposia on Glass and Non-Crystalline Solids: USA (1959), England (1965), Japan (1966), Germany (1968), Canada (1969), Germany (1972), (1973), Egypt (1973), France (1982), DDR (1982)
3. Gordon Conference on Glass. 1954, 1956, 1958, 1962, 1965, 1969, 1971, 1974, 1976, 1978

Current and Recent Research Interests:

1. Small Angle X-ray Studies of Separated Phases in Glass
2. Relationship of Glass Properties to the Melting Atmosphere and History of Glass
3. Crystallization of Magnetic Lead Ferrites from Glass
4. The Mixed Alkali Effect and Glass Properties
5. The Internal Friction of Glass
6. Ion-exchange Mechanisms
7. Viscosity of Glasses
8. Luminescence and Electroluminescence in Glass Systems
9. Role of Modulus and Fracture Energy in the Strength of Brittle Solids
10. Studies of Microheterogeneities in Glass by Laser Light Scattering, Small Angle X-rays, and Electron Microscopy
11. Strength and Fracture Energy of Phase Separated Glasses
12. Effects of Water on Glass Microstructure and Properties
13. Ceramic Encapsulation of Nuclear Waste

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Publications of Guy E. Rindone

1. Rindone, G. E., E. C. Marboe, and W. A. Weyl, Oxidation and Reduction of Glasses by Means of Electrolysis, J. Am. Ceram. Soc. 30 314-319 (1947).

2. Rindone, G. E. and W. A. Weyl, Glasses as Electrolytes in Galvanic Cells: Silver Glasses, J. Am. Ceram. Soc. 33 91-95 (1950).

3. Rindone, G. E., The Spontaneous Growth of Silver Films on Glasses of High Silver Content, J. Soc. Glass Tech. 37 124-28 (1953).

4. Rindone, G. E., Possible Explanation for Gas Evolution after Fining in Barium Glasses Containing Sulfates, Symposium Sur L'Affinage du Verre, pp. 399-421, Paris, June 1955.

5. Rindone, G. E. and J. L. Rhoads, The Color of Platinum, Palladium and Rhodium in Simple Glasses, J. Am. Ceram. Soc. 39 173-80 (1956).

6. Rindone, G. E., Color Centers Formed in Glass by Solar Radiation, Proceedings of the IV International Congress on Glass, pp. 373-89, July 1956.

7. Smith, G. S. and G. E. Rindone, Application of the Oxygen Electrode in Galvanic Cells with Glasses of Different Composition, Glass Ind. 37 437-443 (1956).

8. Rindone, G. E. and R. J. Ryder, Phase Separation Induced by Platinum in Sodium Phosphate Melts, Glass Ind. 38 39-31, 51, (1957).

9. Rindone, G. E., Fining - A Report of the German Society of Glass Technology, a Translation, Glass Ind. 38 Part I p. 489, Part II p. 561 (1957).

10. Rindone G. E., Influence of Platinum Nucleation on Crystallization of a Lithium Silicate Glass, J. Am. Ceram. Soc. 41 p. 41 (1958).

11. Ryder, R. J. and G. E. Rindone, Color and Light Scattering of Platinum in Some Lead Glasses, J. Am. Ceram. Soc. 41 415 (1958).

12. Rindone, G. E., Ceramics Research at Penn State, Part V: The Glassy State, Pittsburgh Ceramist 10(4) pp. 4-6 (1958).

13. Rindone, G. E., D. E. Day and R. Caporali, The Relative Acidities of Glasses Containing Al_2O_3 and TiO_2 as Determined by the Oxygen Electrode, J. Am. Ceram. Soc. 43 571-577 (1960).

14. Ryder, R. J. and G. E. Rindone, The Internal Friction of Simple Alkali Silicate Glasses Containing Alkaline Earth Oxides: I Experimental Results, J. Am. Ceram. Soc. 43 662-669 (1960).

15. Smith, G. S., and G. E. Rindone, High Temperature Energy Relations in the Alkali Borates: Binary Alkali Borate Compounds and Their Glasses, J. Am. Ceram. Soc. 44 72-78 (1961).

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17. Ryder, R. J. and G. E. Rindone, The Internal Friction of Simple Alkali Silicate Glasses Containing Alkaline Earth Oxides: II Interpretation and Discussion, J. Am. Ceram. Soc. 44(11) 532-40 (1961).

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19. Rindone, G. E., Glass Research by Internal Friction Methods, Min. Ind. Bull. 31(4) 1-6 (1962).

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    b) Influence of Microstructure on Glass Strength, pp. 177-191. Recent Advances in Science and Technology of Materials, Vol. II, edited by A. Bishay, Plenum Press (1974).

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61. Faber, K. T. and G. E. Rindone, "SAX and TEM Studies of Phase Separated Soda Lime Silica Glasses Containing Water," Phys & Chem Glasses (accepted for publication).

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65. Shinkai, N., C. R. Kennedy, R. C. Bradt and G. E. Rindone, "The Fracture Toughness of Glass", J. Am. Ceram. Soc. (submitted).

PATENTS

1.	US 2,825,634	Glass Articles, Composition and Methods of Producing Same, March 4, 1958.
2.	US 2,838,408	Glass Compositions, June 10, 1958.
3.	US 2,861,001	Glass Compositions, November 18, 1958.
4.	US 2,906,631	High Dielectric Constant Glass, September 29, 1959
5.	US 2,939,797	Glass Compositions, June 7, 1960.
6.	US 3,197,178	High Dielectric Constant Glass, October 15, 1963.
7.	US 3,145,114	Process for Increasing the Index of Refraction of Glass and An Article Made Thereby, August 18, 1964
8.	US 3,145,114	Reissue 26,2117, June 6, 1967.
9.	US 2,146,682	Optical Glasses, April 6, 1972.
10.	US 3,690,908	High Index Optical Glass, Setpember 12, 1972.
11.	US 3,897,197	New Transparent Low Thermal Conductivity Glass Compositions and Lamp Envelopes Made Therefrom, July 29, 1975.

BOOKS

1. Advances in Glass Technology, Tech. Papers of VI International Congress on Glass, Edited by G. E. Rindone, Plenum Press, New York, 1962, 639 pp.

2. Advances in Glass Technology, Vol. II, Additional Papers of VI International Congress on Glass, Edited by Frederick R. Matson and Guy E. Rindone, Plenum Press, New York, 1963, 428 pp.

3. "Symposium on Nucleation and Crystallization in Glasses and Melts," W. B. Hillig & G. E. Rindone, Co-Chairmen, The American Ceramic Society, 1962.

HEARING ON MATERIALS PROCESSING IN SPACE

Additional Questions for Dr. Guy Rindone

September 14, 1983

1. Other than bioprocessing, do any other opportunities exist in materials processing in space to warrant the establishment of University Centers? If so, is it feasible to establish a single multidisciplinary center? Would sufficient strong technical relationships exist that would promote cross-fertilization between such disciplines?

2. Does a University setting represent any advantage over a national laboratory or industrial facility in stimulating progress in space materials processing research? Could this also be accomplished through a centralized multi-univeristy facility?

3. What type of managerial and programmatic relationships between NASA and the proposed Center would lead to the most productive research environment?

4. Could the Science Working Group constituted under the USRA aegis function in an advisory capacity for the University Center?

5. What do you believe should be the criteria for selection of the University Center?

6. What size Center should be considered appropriate for establishing a viable program in materials processing? What would be a favorable balance of principal researchers, post-doctoral students, graduate students, visiting researchers, etc?

7. What relationship would be appropriate between industry and the University Center?

Reply by Guy E. Rindone to Additional Questions

September 29, 1983

1. In answering the additional questions, and particularly question 1, concerning the establishment of centers for materials processing in space I should like to call your attention to a study conducted by USRA for the MSFC under Grant NGR 47-102-003 and reported under the title "The Establishment of an Independent Institute as an Integral Part of the NASA Program in the Effect of the Space Environment on Materials and Processes" on December 13, 1974 by A. R. Kuhlthau, President of USRA at that time. I was a member of the study team. A copy of this report is available through USRA headquarters.

   This report recommends the establishment of a single multidisciplinary center because it recognizes that space processing is split into many disciplines in which the main issues involved are the phenomena of separation and solidification. Therefore, in a multidisciplinary center there would be sufficiently strong relationships that would promote cross-fertilization between the disciplines.

2. A multidiscipline center in which scientists from many universities participate should be located at a site independent of a particular university or of a particular industry. This is important if the objective is to promote greater interaction between scientists from various universities and industries. Selection of a single university for a multi-university center would lead to problems whereby the particular university administration at the center would dominate and hence discourage participation by other universities. It would be more desirable to locate the center near a NASA center which offers some facilities for materials processing in space research. The availability of drop towers and drop tubes would be an example. Alternatively, the center should be located near but not at a research facility - university, industry or government - where there is an availability of advanced research equipment to center personnel.

3. The governing body should be vested in a consortium of academic institutions, the Director should be appointed with the approval of NASA and a direct programatic liaison should be established between the Director and NASA.

4. If a single University Center is established in a particular field then the corresponding science or discipline working group under the aegis of USRA could function in an advisory capacity. If a multi-discipline center is established then the USRA Science Council on Materials Processing in Space could function in an advisory capacity.

5. Criteria for a single University Center would be:

   a) an established reputation of excellence in the field,
   b) exceptionally good facilities for research,
   c) recognized scientists as leaders in their field.

6. For a viable program involving multi-disciplinary in-house research, the center should have as a minimum a full time director, at least two permanent scientists with established reputations, a continuing source of visiting scientists - including post docs, perhaps 4 or 5 at a time to cover the various disciplines, and a commensurate number of graduate students who may accompany their visiting scientist advisor in addition to graduate students assigned to the permanent staff.

7. The relationship between industry and the Center has been addressed by me in my testimony on pages 49 and 50. I should like to emphasize that a strong industry-center coupling be established in which there is a regular exchange between industry scientists and center scientists. There should be adequate industry representation on the Center's advisory board.

Mr. VOLKMER. Thank you very much, Dr. Rindone.

Now, on the establishing university center for material processing or microgravity research science research, as you know, we added additional funds in the authorization and there are some in the appropriations. Do you—and does the association support—from your testimony, it appears to support the funding and starting up of these centers?

Dr. RINDONE. Yes; I think there's no question that centers such as you have in mind are very important for the program. I would caution, however, and I think the association feels this way, that these centers should have their main thrust in gaining new knowledge rather than directed toward making new products.

In other words, in the biological field, these centers must be a basis for determining the concepts, the phenomena, the procedures in a fundamental way and then have these—this knowledge applied at some point or another to the improvement of pharmaceuticals or some other biological material.

Mr. VOLKMER. Are we still in the embryonic stage as to the effect of gravity on certain elements, combining or biological formations, et cetera?

Dr. RINDONE. Well, I'm not an expert in the biological field, but I'm sure that there's a great deal of knowledge to be learned. I know that much of what has been done in space has been predicted on the basis of knowledge of the biologists working in this field.

But there are many areas that are uncertain that—not only in the biological field, but in any of the other materials fields—that we just don't know what certain phenomena—how certain phenomena are going to be affected in the space environment or in a microgravity environment.

Mr. VOLKMER. Do we need to do more basic research here on Earth to, you know, develop the space applications?

Dr. RINDONE. Oh, I think there's no question about that. I think that if we're going to get good thrust in the materials program, that you have to have a very sound base with regard to basic research. This does not mean that the basic research should not have an ultimate goal in an applied area. In fact, this is extremely desirable.

One of the most advantageous features that I've experienced in my years as a professor is in my consulting work with industry, where, in my contacts with industry, we find out what are some of the underlying problems they face. And having an insight into these problems, this directs one a little bit more in his own basic research to study the phenomena which may lead to a better understanding.

Therefore, I think in the space program—the material space program—we must have a good ground base which is established not only by people in universities and research organizations, but in cooperation with people in industry who have certain problems that the other researchers should be made aware of.

Mr. VOLKMER. I should have asked this of Mr. Halpern, but I ask it of you, and not to embarrass Mr. Halpern, but has the University Space Research Association—I know you've worked with NASA on a lot of development in material processing and space program—but have you been asked to assist—or would you be willing—the association—maybe you can't speak for them, but be willing to work with NASA in developing the university centers?

Dr. **Rindone**. Oh, by all means. There are several institutes now which USRA is involved with with NASA and these institutes—several of these are located at the NASA centers and USRA works very, very closely with NASA on this and they certainly would be very willing to cooperate in whatever means NASA would like it to.

Mr. **Volkmer**. After we have the center—a center or centers—established, do you see merit in promoting international participation in those centers?

Dr. **Rindone**. Definitely. I think that particularly if the centers devote their efforts to fundamental research, which is microgravity-related, that we need to get the cooperation of the scientists from other countries and the fact that this is basic research, I think, removes the danger of transfer of technology which we might feel is not desirable, although I feel that most of our interchange—I think our interchange with the foreign countries ought to be with friendly nations at this point, so—but in any event, the results of such work will always be published and this is available to the entire—entire world.

Mr. **Volkmer**. You see no problem with technology transfer in the event of international cooperation?

Dr. **Rindone**. Not if the centers are devoted to fundamental research.

Mr. **Volkmer**. In what ways, has the—what some people have characterized as slow progress of material processing in space—impacted on development of materials beneficial to society?

Dr. **Rindone**. I think this is a very difficult question to answer. We really don't know because we don't know yet what the benefits, the direct benefits of space are going to lead to. We can anticipate that we can do certain things like containerless processing, and if we had a means now of melting something in space and positioning it in a furnace with the proper positioning device, we have the opportunity to learn, can we make some new materials because they don't have the contamination of the container? But we haven't run these experiments yet. We have indicatations that this will be true, but we really don't know whether—I cannot say that this has held back the materials field.

Mr. **Volkmer**. You're specifically involved, as I understand it, in ceramics?

Dr. **Rindone**. Glass and ceramics, yes.

Mr. **Volkmer**. Do you envision any possibilities in that area?

Dr. **Rindone**. Very definitely. I think glass and ceramics, particularly, offer some exciting opportunities. For example, there are many materials that we cannot melt on Earth because of the high temperatures involved would cause them to react very drastically with their container. And so instead of having this pure material, we would have a heavily contaminated one.

Now, if we can melt these at high temperatures, we have the opportunity to produce glasses, for example, or if these melts then crystalize to form crystalline materials which we could not produce on Earth, and these materials are predicted—some of them—to have very superior properties. They could have superior optical properties, for example.

Mr. Volkmer. Now, I'll get back to the university. I know on your statement, you address this to some extent.

What would be the university center's relationship between—or should it be between they and industry?

Dr. Rindone. Well, I think a center should have the counsel and the advice of industry in certain parts of its program. In other words, I think it would be well, and some research organizations and universities do this, to have an industry-coupled program whereby representatives of various industries in the materials field, for example, would meet on a regular basis with the scientists involved at the centers where there would be an exchange of information between those in industry with regard to their problems and the information which is gained by the scientists.

In other words, we want a direct transmittal of the latest results in the centers to industry and—an effort to coordinate and to inform the scientists of how these concepts apply or don't apply and what are the concepts they need to have further knowledge on.

Mr. Volkmer. I believe that—and I may be wrong, but from my discussions with the Mc-Dak people, I believe they have some type of a working agreement with Washington University in St. Louis in the biological field there, where one develops the possibility of the type of pharmaceutical—or the use of it——

Dr. Rindone. Yes.

Mr. Volkmer [continuing]. While Mc-Dak, then, would take that and develop the manufacturing of it and the——

Dr. Rindone. I see.

Mr. Volkmer [continuing]. Sale of it.

Dr. Rindone. Well, it's not unusual for industry to support university research whereby they maintain contact with the research, not necessarily directing the research, but maintain the contact so there is good liaison between the two. No; I think that would be desirable.

Mr. Volkmer. The gentleman from California have any questions, Mr. Lowery?

Mr. Lowery. I have no questions, sir.

Mr. Volkmer. I'll get back to the question I asked that relates to your statement and the question I asked Mr. Halpern on the tension between the immediate achievement of commercially important products and those persons who wish to just do research.

You speak of this—you believe that this tension is healthy or unhealthy or——

Dr. Rindone. Well, I think it's healthy if it's put in the proper balance. The question is, who does this tension exist between? Well, I think there are two sources. One source is the tension that exists between the basic scientist who wants to study phenomena and principles and the other are some—and these scientists involve people in NASA as well as universities and industry—and the other tension—and the other side is between people who are involved in NASA, who are involved in industry and who are involved in Congress in seeing a commercialization of space.

Now, I think it would be a mistake to try to let people feel that we're going to immediately commercialize space and make things there better. There may be some things we can, but I think we need the incentive by these people that, sure, we hope that we're going to do this and if we could make this in space, if we could do this and do this in space, we've achieved something.

But I think if you have the commercialization aspect overemphasized and then we have failures, then the space program is going to suffer.

So, I think we have to temper this with a balance that we have the proper ground-based research prior to performing the experiment so at least we have a reasonable knowledge for believing that the experiment will be success—successful.

Mr. VOLKMER. Would you also comment upon the utilization that what we learn in space being able to do something better here on Earth actually?

Dr. RINDONE. I think that is one of the major features. We can study, for example, one of the major advantages of a microgravity field is in dealing with fluids, liquids in particular. But here we have liquids now that are not going to be affected by differences in temperature insofar as their activity.

If you have a liquid in a microgravity field, and one part is hotter than another, the hotter part expands; it becomes lighter.

Now, in a gravity field, that liquid—the lighter liquid—would rise to the surface, and so you have convection or a mixing. But in a microgravity environment, you wouldn't have this. And so it's possible to make studies of the effects of density gradients in a liquid. It may be possible to produce liquids which then can be solidified, either as glasses or crystallized, that have these density gradients which lead to unusual characteristics and unusual properties.

So, there's no question that the space environment would be very beneficial in the studies.

Mr. VOLKMER. To get back to the tension and how do we make it so it remains—the tension itself remains creative—constructive rather than destructive through the total program?

Dr. RINDONE. Well, I think you just have to make sure that we don't go overboard in one direction or the other. I—we have to have sensible people involved who are aware of the possibilities and don't get swept off their feet by visions which are beyond the realm of reality——

Mr. VOLKMER. In other words, you have a balanced program, then?

Dr. RINDONE. Right.

Mr. VOLKMER. The gentleman from California?

Mr. LOWERY. Mr. Chairman, to follow up on your last line of questioning, tension, whatever, interfacing. Dr. Rindone, can you comment on the degree of interface and cooperation there is amongst various Federal agencies now on materials science research, Department of Defense, Bureau of Standards, National Science Foundation, National Institutes of Health, as well as NASA? How are they resolving some of these questions?

Dr. RINDONE. I'm not sure I understood your question. Was your question, how they interface with NASA or how they interface with——

Mr. LOWERY. Interface with one another, yes. Specifically, NASA.

Dr. **Rindone**. Well, I don't——

Mr. **Lowery**. The knowledge here on Earth, let alone that from the shuttle, on materials processing?

Dr. **Rindone**. If your question is NSF, for example: supporting any research which would increase our knowledge of research in the space program?

Mr. **Lowery**. Yes.

Dr.. **Rindone**. Not to any great extent that I am aware of.

Mr. **Lowery**. The other——

Dr. **Rindone**. I——

Mr. **Lowery** [continuing]. Agencies?

Dr. **Rindone**. I have no direct knowledge of any significant support by any other agency in these directions. There may be some that I'm not aware of.

Mr. **Lowery**. That's it.

Thank you, Mr. Chairman.

Mr. **Volkmer**. Thank you very much, Dr. Rindone, I appreciate the testimony. You've been very helpful and I look forward—I'm sure you do, too—look forward to working for a—like you say, balanced program for research and development of materials processing in space.

Wait a minute, I have one here. Oh, yeah. All right, I have a letter here from the National Research Council that—invitation to testify and not—yeah, they won't be able to attend and however, they do—I'd like for this to be part of the record—made part of the record.

[The letter referred to follows:]

NATIONAL RESEARCH COUNCIL
COMMISSION ON ENGINEERING AND TECHNICAL SYSTEMS
2101 Constitution Avenue Washington, D.C. 20418

SPACE APPLICATIONS BOARD
(202) 334-3272

7 September 1983

Honorable Harold L. Volkmer
Chairman, Subcommittee on
Space Science & Applications
Committee on Science and Technology
Suite 2321 Rayburn House Office Bldg.
Washington, D.C. 20515

Dear Mr. Chairman:

Thank you for the invitation to testify on September 14 during the Subcommittee's review of the NASA program on Materials Processing in Space. Unfortunately, the Space Applications Board's experts in this field, Dr. Gordon Millar and Dr. William Slichter are unable to appear on that date because of important prior commitments. However, the Board is pleased to respond in writing.

The NASA program was reviewed intensively by committees of the Board in 1977 and 1982. The Board recommended that NASA concentrate its efforts on an earth-based program in several areas of materials science and engineering and be prepared to carry into space only those experiments that the earth-based program shows would benefit from a near-weightless environment.

NASA followed this advice and completely restructured its program, involving as we suggested the national community of materials scientists and engineers. The program has been reviewed annually at Space Applications Board meetings and the Board has followed with interest the several NASA program status reports that have been published periodically, noting that NASA continues to follow the Board's advice.

During his testimony on behalf of the Board before the Subcommittee on 24 February 1983, member Willis Shapley suggested that the program could benefit from a modest increase in funding and the Subcommittee did authorize an increase. The Board does not know of any additional steps that need to be taken at this time. We believe that the direction NASA has taken in this program will eventually bear fruit.

I hope that this information is helpful to the Subcommittee. We will continue to monitor this important program and will be pleased to come forward when additional work has been done by NASA and the materials community.

Sincerely,

for George A. Harter
Chairman

bcc: D. Hazen
B. Edelson
R. Halpern

The National Research Council is the principal operating agency of the National Academy of Sciences and the National Academy of Engineering to serve government and other organizations

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Mr. VOLKMER. And that will conclude our hearing for today and we will recess until tomorrow for continuation of these hearings and thank you, again, very much, Dr. Rindone, and also, Mr. Halpern. Thank you very much.

[Whereupon, at 11:15 a.m., the subcommittee was adjourned, to reconvene, subject to the call of the Chair.]

REVIEW OF MATERIALS PROCESSING IN SPACE
1983

THURSDAY, SEPTEMBER 15, 1983

House of Representatives,
Committee on Science and Technology,
Subcommittee on Space Science and Applications,
Washington, D.C.

The subcommittee met, pursuant to call, at 9:30 a.m., in room 2325, Rayburn House Office Building, Hon. Harold L. Volkmer (chairman of the subcommittee) presiding.

Mr. **Volkmer**. Good morning. The subcommittee will come to order.

This session will conclude our oversight hearings on the NASA materials processing hearings.

Today we have a very distinguished panel who will be asked to comment on this program and, more particularly, on our recommendations that NASA establish one or more university centers for base research—for basic research on separation and purification of organic materials.

We are pleased to have a panel which represents the broad spectrum of interests involved. Dr. Jacob Stucki has a great deal of experience with the pharmaceutical industry, ultimately one of the possible major issues of this technology. Prof. Merton Flemings played a major role in establishing a materials research center at MIT. Also we have Dr. Dudley Saville from Princeton University, and Dr. Milan Bier from the University of Arizona, who are active in this field of research and well known for their contributions.

We are, of course, aware of the McDonnell Douglas activities. Our belief is that other such promising areas for development are probably awaiting exploration and exploitation. A prerequisite seems to be development of a sound base in terrestrial sciences recommended by the National Research Council's Space Applications Board.

We have no assurance that the ultimate commercial payoff in this work will be space manufacture of wonder drugs. Nevertheless, we feel confident there will be benefits from a scientifically healthy and creative program for basic research into phenomena that can be used advantageously.

[The prepared statement of Mr. Lujan follows:]

Prepared Statement of Hon. Manuel Lujan, Jr.

Thank you, Mr. Chairman. Yesterday we heard some very interesting testimony on the NASA materials processing program. The witnesses emphasized the importance of the shuttle in making possible the next phase of research efforts.

I believe that support for these R&D efforts should be one of the top priorities of the shuttle. This allows NASA to continue to maintain its strength in its primary role as a research and development agency.

In addition to the shuttle availability, I am interested in hearing from today's witnesses about how we can provide strong support to the materials processing program and insure its eventual commercial success.

Mr. VOLKMER. I would like to welcome our first witness on the panel, Dr. Stucki. We will follow with then Dr. Flemings—Professor Flemings, Dr. Saville, and Professor Bier, in that order.

Mr. STUCKI. Is this on?

Mr. VOLKMER. Yes.

Your statements—I will say that all of your statements will be made a part of the record, and you may either review those or you may summarize, however you so desire.

STATEMENTS OF DR. JACOB C. STUCKI, VICE PRESIDENT FOR PHARMACEUTICAL RESEARCH, THE UPJOHN CO., KALAMAZOO, MICH.; DR. MERTON FLEMINGS, PROFESSOR, MATERIALS PROCESSING CENTER, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE, MASS., ACCOMPANIED BY GEORGE B. KENNEY, ASSISTANT DIRECTOR, MATERIALS PROCESSING CENTER, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE, MASS.; DR. DUDLEY A. SAVILLE, DEPARTMENT OF CHEMICAL ENGINEERING, ENGINEERING QUADRANGLE, PRINCETON UNIVERSITY, PRINCETON, N.J.; AND DR. MILAN BIER, BIOPHYSICS TECHNOLOGY LABORATORY, ELECTRICAL ENGINEERING BUILDING, UNIVERSITY OF ARIZONA, TUCSON, ARIZ.

Dr. STUCKI. OK.

Mr. Chairman, thank you for the opportunity of appearing before this committee. As you suggest, I am going to summarize my written statement.

The pharmaceutical industry has long recognized the need for public funding of basic research I believe the committee's proposal to establish a university center for basic research in the separation and purification of organics in a low-gravity environment will receive general support in the industry.

In my written testimony the attributes of and the manner in which such a center could be used is illustrated by descriptions of some of the experiences Upjohn has had with other university centers. Our interactions with university centers of excellence have ranged from didactic experiences for the purpose of learning technologies to collaborations where each party to the collaboration makes an intellectual contribution to the solution of a problem.

In all interactions, we protect the rights of inventors and their institutions. We normally make a financial contribution to the effort with grants or consultantships or royalties alone or in combination.

Excuse me.

The limited scope and funding of the charter, as I understand it, of the center of excellence under discussion suggests to me that the center should be located in a university setting as proposed by the committee.

However, I have no basis for contending that it could not just as well be located in a Government laboratory. Easy access to the center by interested scientists and organizations will be of paramount importance. The location and governance of the center should be planned so that access is encouraged rather than discouraged.

It is our experience that university laboratories are inherently accessible. However, we have no direct experience with such centers in either Government or commercial laboratories.

I believe the pharmaceutical industry will be very interested in the results from research which might be conducted in such a center, and would be interested in rapid transfer of separation technologies to the industrial setting.

Now I have some doubts that there is a pressing need for low-gravity separation and purification of organic chemicals. However, with the increasing probability that new pharmaceuticals will be large and complex molecules, there is an increasing probability that new and better separation and development techniques will be required at some time in the future.

In summary then, one, we would encourage the establishment of the center of excellence at a university; two, the center should concentrate on methodologies and should be widely accessible to industrial scientists; three, guest investigators should be welcomed and it should be possible for industrial scientists to engage in collaborations with scientists in the center, whether or not the collaboration is specifically funded by the interested company.

It should be possible for corporate funds to be placed in the center for the support of the center's research programs if this is desired. And, four, if projects are hardware oriented and specific patentable instrumentation is developed, instrument companies involved should have the opportunity to derive reasonable returns on their investments. And I would say parenthetically that Upjohn is not in the instrument business.

And five, processes or techniques developed at the center should be rapidly and freely transferred to the public and private sector laboratories.

This completes my oral statement, Mr. Chairman.

[The prepared statement, plus answers to questions asked of Dr. Stucki, follow:]

NASA

TESTIMONY OF JACOB C STUCKI, Ph.D,
VICE PRESIDENT FOR PHARMACEUTICAL RESEARCH
THE UPJOHN COMPANY, KALAMAZOO, MICHIGAN

Mr. Chairman, I appreciate the opportunity of appearing before this committee for the purpose of commenting on the Committee's recommendation that NASA establish a university center for basic research in the separation and purification of organic materials under conditions of microgravity.

The U.S. pharmaceutical industry is highly dependent upon basic research, a large part of which is funded by various federal agencies. It is neither possible nor appropriate for the industry to fund or to conduct all of the basic research required for us to remain competitive in the world pharmaceutical markets. Our reliance upon university research, funded in part by the public, is widely acknowledged. Any initiatives to increase public funding for basic research which might be even remotely useful to the pharmaceutical industry are generally encouraged by industry management.

It is my opinion that the Committee's proposal to establish a center for basic research in the separation and purification of organics in a low gravity environment will receive general support by research management in the pharmaceutical industry, although it should be understood that I do not speak for research management in the industry in any official or even quasi official capacity. I believe industrial research managers will see this center as being potentially capable of identifying and developing basic separation and purification methodologies that will have application in both the discovery and production of new pharmaceutical and diagnostic products.

The attributes of such a center and the manner in which industry could utilize the output of this center might best be illustrated by experiences which The Upjohn Company has had with academic centers of excellence in the past.

In 1957, nuclear magnetic resonance (NMR) was a new and rapidly emerging technique for the determination of the structures of organic coumpounds. The instrumentation required was available at only a very few university centers. Trained NMR spectroscopists were rare, delivery times for instruments were very long and NMR spectrometers were very expensive.

Upjohn researchers and research management had been watching the development of the field of NMR and decided that in-house skill in the application of NMR techniques was essential. The company placed an order for an NMR spectrometer and selected one of its organic chemists, Dr. George Slomp, to become an NMR spectroscopist. Dr. Slomp was sent by Upjohn to the laboratory of Professor H.S. Gutowsky at the University of Illinois to learn NMR spectroscopy. Dr. Slomp spent six months with Professor Gutowsky and returned to Upjohn well-trained in both the science and the techniques of NMR. He has gone on to become a recognized expert himself in the field of NMR, both within The Upjohn Company and in the external scientific community. The Upjohn Company supported the training of Dr. Slomp with suitable grants to the University of Illinois, but it recognizes that by no means could it compensate the system in its entirety for the availability of NMR expertise at Illinois.

More recently, one of our employees, Dr. T. A. Scahill, prior to obtaining his doctorate, spent a period of time at the University of Kentucky learning high field NMR technology and its application to biomolecular structure problems. Scahill's professor, Dr. S. Smith, was retained as a consultant to The Upjohn Company and advised Dr. Scahill on thesis work which he conducted at Upjohnand Kentucky. The outcome of this cooperative endeavor was that Dr. Scahill obtained his Ph.D. degree at Kentucky, and has become Upjohn's expert in the application of high field NMR to complex molecules of biological origin.

One of the more complex interactions we currently have underway involves two university laboratories, the National Science Foundation and three laboratories at The Upjohn Company. The objective of the project is to isolate, purify and determine the dimensional structure of the hormone binding domain, i.e. the active site, of the chicken oviduct progesterone receptor. Each party to the collaboration is able to bring some unique skills and knowledge to the project.

Upjohn provides receptor binding data on a wide variety of steroid structures made in our laboratories, provides large scale pilot plant processing of chicken oviducts, and a grant to one of the universities. Dr. B. W. O'Malley's laboratory at Baylor University is conducting initial specialized purifications and Dr. A. Tulinsky's laboratory at Michigan State University will carry out the crystallization and x-ray structure determination of the steroid binding fraction. Should the progesterone receptor be spatially defined, Upjohn (and others) will be able to design molecules that can more efficiently interact with the receptor and either activate or immobilize the receptor as desired. This collaboration is in process and the outcome unknown at this time.

Another example of interaction with a university center of excellence concerned the application of quantum mechanical methods to the design of large molecules of biological interest. Over a ten-year period Upjohn supported a collaborative research program with Professor R. E. Christoffersen at the University of Kansas. Upjohn provided both a consultantship to Dr. Christoffersen and a grant to support some of his research during this ten-year period. Dr. Christoffersen and his students developed computational methods and Upjohn scientists applied these methods to compounds of interest to our biologists. Information obtained in our laboratories was fed back to Dr. Christoffersen so that he and his students could refine and modify their computational programs. The interplay between our laboratories was truly collaborative with the academic laboratory doing method development and the Upjohn laboratories applying the methodology and suggesting methodological alterations based on results obtained in application.

These examples are a few of the many interactions Upjohn has had and continues to have with university centers of excellence. These interactions range from didactic experiences for the purpose of learning basic technologies as in the first two examples, to collaborations where each party brings an intellectual contribution to the exchange, as in the last two examples.

Upjohn and other companies also have many interactions with academic colleagues in which a patentable entity is the possible outcome of the interaction. In these instances, the company is careful to protect the rights of the inventors and the institutions to which the inventions may be assigned, most often a university research foundation or the like. Agreements surrounding the work are always fashioned to maximize both the return to the owner of the invention and the likelihood that the invention will be developed.

The examples of interactions cited in this presentation are of the type not likely to yield invention, but instead involve the transfer of basic information from one scientist or laboratory to another. In such interactions, Upjohn would expect to make some contribution to the support of the interaction. In some cases this contribution will be monetary in the form of grants and/or consultantships; in other cases, Upjohn's contribution will only be intellectual. That is, the Upjohn scientist in the interaction will contribute to the intellectual interchange as does the academic scientist. In many cases the Upjohn contribution will contain elements of both.

A center of excellence of the type proposed by the committee would be a welcome addition to the variety of basic research centers already in existence, including government laboratories such as those of the National Institutes of Health upon which the entire pharmaceutical industry, as well as other segments of the economy, depend so heavily. The limited scope and funding of the charter of this particular center of excellence, namely space-borne separation and purification of organic chemicals, suggests that the center should be located in a university setting, as suggested by the committee, as opposed to a commercial or a government laboratory.

While there are several models for the management of such a center of excellence in a university setting, a model of maximum simplicity should be adopted. Access to the center should be easy, collaborative research should be encouraged, financial as well as intellectual contributions from industry should be expected and the likelihood that any one industrial collaborator would gain proprietary advantage should be minimized.

The models of interaction cited in this presentation should be emulated, viz., those in which patents or trade secrets are unlikely but where methodologies are rapidly developed and transferred to laboratories in the private as well as the public sector. NMR technology is an example. Almost all laboratories use NMR spectrometry. The motivation to acquire the capability as rapidly as possible is a competitive motivation, but it is not one that partakes of either patent protection or secrecy--at least from the point of view of the pharmaceutical company. It is acknowledged that companies that develop and sell instruments used in the manipulation of these technologies might view the establishment of the proposed center of excellency in a somewhat different light.

The pharmaceutical industry would very likely send guest workers to such a center. The conditions would be determined by the state of the technology under development and its relation to the particular needs of each individual company, as well as to accessibility of the center as discussed previously.

The immediate need for low gravity separation and purification of organic chemicals is problematic, in my opinion. However, with the increasing probability that new pharmaceuticals will be large and complex molecules of biological origin rather than the simpler organic compounds of the past, there is a corresponding increasing probability that new and better separation and purification techniques will be required. The McDonnell Douglas space electrophoresis experiments which have been widely discussed are an encouraging beginning.

In summary, we would encourage the establishment of the center of excellency at a university. The center should concentrateon methodologies and should be widely accessible to industrial scientists. Guest investigators should be welcomed and it should be possible for industrial scientists to engage in collaborations with scientists in the center whether or not the collaboration is funded by the interested company. It should be possible for corporate funds to be placed in the center for the support of the center's research programs. If projects are hardware-oriented and specific patentable instrumentation is developed, instrument companies involved in the development should have opportunity to derive a reasonable return on their investments. Processes or techniques developed at the center should be rapidly and freely transferred to the public and private sector laboratories.

OCT 5 1983

THE UPJOHN COMPANY
KALAMAZOO, MICHIGAN 49001 U.S.A.

PHARMACEUTICAL RESEARCH
AND DEVELOPMENT
Office of
JACOB C. STUCKI, PH.D.
Vice President
TELEPHONE (616) 385-7053

September 29, 1983

Representative Harold L. Volkmer, Chairman
Subcommittee on Space Science and Applications
U.S. House of Representatives
Committee on Science and Technology
Suite 2321 Rayburn House Office Building
Washington, D.C. 20515

Dear Representative Volkmer:

I am pleased to present responses to the questions which you presented in your letter of September 15 to the panel members at the hearing on Materials Processing in Space.

1. *Given the necessary limitations in funding, what should be the technical focus for the Center? How should these priorities be established and who should establish them?*

   Reply: Various investigators interested in materials processing in space should collaborate with NASA representatives in the preparation of proposals. The priorities for implementation of these proposals should be established, as is the practice at the NIH, through a peer review process.

2. *What would be an adequate level of funding for continuous operation of the Center? How could additional non-NASA funding be secured?*

   Reply: I am not qualified to judge the adequacy of funding. Additional non-NASA funding could be sought in the same manner as biomedical funding is sought. Proposals to industrial sponsors are routinely made and when there is a compatibility of interests, funding is provided.

3. *To what extent should theoretical mathematical modelling be a part of the Center's activities? How can we ensure that the theoretical effort supports experimental activities at the Center?*

Reply: Theoretical mathematical modelling should definitely be a part of the Center's activities. To ensure that the theoretical efforts support experimental activities, the program should have a scientific manager of stature.

4. *How can we promote international participation in the Center's activities without, at the same time, introducing undesirable technology transfer?*

Reply: The program on Materials Processing in Space must be willing to give something in the way of technology transfer to get something back. The research results should be published in the appropriate journals. Every attempt should be made to keep the research and the results unclassified.

Yours sincerely,

Jacob C. Stucki

Mr. **Volkmer**. All right.

Professor Flemings.

Dr. **Flemings**. Yes; thank you.

I also will summarize only a few aspects of this rather lengthy written document which we have here describing the Materials Processing Center at MIT.

The low-gravity environment of space provides a new dimension for us in the materials field for research on materials and materials processing. The absence of convection in liquids and the capability for containerless processing, for example, made possible in this environment provide us with new opportunities for research into the fundamentals of materials processing, as well as providing at least the possibility of ultimate commercial exploration in terms of processing in space.

NASA has recognized this dual potential, both for research and commercial development, in establishing their materials processing in space program, and also in forming and helping us form the Materials Processing Center at MIT.

NASA's key initial support and continuing—continued funding of our center has been essential to the development of the broad role the center now plays at MIT and in conjunction with industry.

The center was founded in 1980 with an initial grant from NASA of $300,000 to establish a broad fundamentally oriented research base in processing, and its activities have now grown to a total of nearly $4 million. NASA support now totals about $800,000 or about 20 percent of the center's activities. Another 40 percent of the support comes from industrial sources. And so, that—NASA's support has been effectively leveraged to promote industrial support and interaction and to promote research activities of relevance, both to ourselves, to the space program and to industrial concerns.

The activities of the center now involve 19 faculty members, 50 graduate students, over 20 staff members, and includes representatives from a number of different departments and several different schools within—within MIT.

The—the—the NASA base has—well, NASA's low-gravity research platforms here and this NASA research base provide a unique opportunity, in our opinion, for obtaining information and insight critical to the control and study of materials processes, both on Earth and—and—and—and in space. And that's been a concept that's been central to the formation of the materials processing center, namely, that it could—that it could contribute both to processing in space, but also that it could—could contribute to the problems we have on Earth in terms of general processing, manufacturing and productivity.

I don't want to go into the long, lengthy statement following concerning our national needs in—in processing and productivity in terms of competition with—with foreign countries. But we have assumed within—within this center, and within this $4 million budget, only 20 percent of which now comes from NASA, we have assumed major obligations in our own minds, both to work on space and space processing and to develop—and to devote an extensive portion of our resources to—to the fundamentals of materials processing in a terrestrial environment and to interaction with industry in that regard.

If I may just go to the end for a few comments from the closing words of this lengthy document which describes in detail the current programs we're doing and the current types of interaction we have in industry.

Let me simply say that—that in the light of the few words I have said here and in the light of this much longer document, it's clear that I personally support the concept of federally supported focused basic research within university centers of excellence that are in support of both basic focused research and of industrial innovation and new process and product development.

Government-university-industry collaboration along these lines offers, in my opinion, many benefits and opportunities for all parties concerned.

I will stop there.

[The prepared statement of Dr. Flemings follows:]

Testimony at Hearing of

Subcommittee on Space Science and Applications
U.S. House of Representatives
September 15, 1983

The Development of the Materials Processing Center at M.I.T.

by

Merton C. Flemings, Toyota Professor of Materials Processing
Head, Department of Materials Science and Engineering
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

This statement is submitted to provide background information for the Space Science and Applications Subcommittee's hearings on NASA's program for Materials Processing in Space. It examines the three and one half year experience of a Center of Excellence at M.I.T. in Materials Processing, including: (1) the motivation for establishing the Materials Processing Center, (2) the generic research programs of the Center, (3) modes of interaction with industry, and (4) recommendations.

I. THE ESTABLISHMENT OF THE MATERIALS PROCESSING CENTER AT M.I.T.

NASA's Interest in and Contributions to Materials Processing

The low gravity environment of space provides a new dimension for research on materials and materials processing. The absence of convection in liquids and the capability of containerless processing, possible only in this environment, provide many particularly exciting and potentially fruitful opportunities. In particular, these unique processing conditions provide not only new experimental materials and processing data, but also the potential for developing new, commercially viable materials processing techniques, particularly in high temperature, high value-added materials. NASA recognized this potential for both research and commercial development and, as only one component of their effort, served as a big factor in the establishment of the Materials Processing Center at M.I.T.

NASA's intitial and continued funding has contributed significantly to the research and industrial activities of the Center and has catalyzed its expeditious development. Founded in 1980 with an initial NASA grant of $300,000 to establish a research base in materials processing, the Center has expanded to a current annual research budget of $3.9 million. This support has expanded beyond the initial Materials Processing Research Base program to include funding of large, focused programs with a total budget of $815,000. NASA support has been effectively leveraged to promote research activities of particular relevance to both the Space Program and industrial concerns. Nearly 40 percent of the Center's research budget is provided by industrial sources. The various research activities of the Center involve 19 faculty members, 52 graduate students, and 22 staff members, representing six departments, laboratories, and centers at M.I.T. including the Chemical Engineering, Materials Science and Engienering, Mechanical Engineering, Electrical Engineering, and Physics Departments and the VLSI and the Energy Laboratories.

NASA's low gravity research platforms provide a unique opportunity to obtain valuable information and insight critical into the understanding, control, and efficiency of both terrestrial and potential extraterrestrial materials processes. Thus, NASA's mission and the impact of low gravity studies is much broader than just processing in space in that it affects industrial production and productivity in general.

A National Need

Mounting foreign competition threatens American technological leadership in basic processing industries as well as our ability to build advanced systems. The Center was created in 1980 in response to a recognized national need to counter this threat by enhancing basic research and stimulating industrial innovation. In 1979, the National Research Council reported

> "The near absence in our universities of research in materials-processing and manufacturing technology denies the country a potential source of new ideas and innovation. Furthermore, it means that the universities are not exposing young people to current advances in the field."*

During the previous 25 years, considerable attention and government funding had been focused on materials science, the fundamental study of structure and structure-property relationships. The engineering side, particularly materials processing, had taken a back-seat in terms of research expenditures, academic interest, and creative output. Yet, when considering specific national technical needs, the field of materials processing is often of central importance. America's productivity and ability to produce competitive advanced systems in electronics, communications, aerospace, energy, and transportation are directly coupled to advances in materials processing and manufacturing technology.

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* Science and Technology, A Five Year Outlook, National Research Council, W.H. Freeman Co., San Francisco (1979).

Recognizing this national need, M.I.T.'s Materials Processing Center has brought together the faculty, staff, and students necessary to contribute effectively to broad materials processing problems and opportunities. For the past three and a half years, the Materials Processing Center has provided a focus and forum in which academic, industrial, and government personnel can broaden their knowledge while collaboratively developing new scientific and technological skills in materials processing. A key component of this effort is the expansion of the talent base by the recruitment of top students to the field.

Research Activities of the Center

The research activities of the Center may be divided into the following two broad categories:

1) the Materials Processing Research Base, that is, work which is directly supported by NASA, and
2) the overall materials processing research effort, which is supported by NASA as well as other governmental or industrial sources.

The NASA supported Materials Processing Research Base provides the Center with discretionary funding for seed research projects relevant to low gravity materials processing. While very substantial in its own right, the Materials Processing Research Base has further served as an extremely important nucleus for facilitating the growth of research efforts in related areas. A prime example is Professor Donald Sadoway's electroprocessing program, which was literally launched in 1980 by funds provided by the NASA Materials Processing Research Base program. With this initial funding, which supported one graduate student, Professor Sadoway has developed a metals electroprocessing program which currently supports six students and staff with a budget in excess of $500,000 (from both industrial and government sources). We cannot emphasize enough the fact that NASA's founding support to our Center of Excellence was critical in launching the career of this young faculty member in an innovative area with expanding industrial interest and potential space applications.

Discretionary funding from the Materials Processing Research Base has also been used to support the initiation of a computer-aided and adaptive materials processing program. Professor Thomas Eagar's program in adaptive control of welding processes leads this effort and seeks to develop a means for automatic, in-process detection and control of weld defects. The technique being developed collects data from a unique sensor (the weld plasma), electronically analyzes this signal, and returns feedback information for process control based on an accurate model of the overall welding process. Again, the environment of the Center facilitates such a collaborative effort by experts in various, disparate research groups. Through this program, the Center draws attention to process control and the automation of materials processes. Our initial program spawned two other, separately funded efforts in process control: Dr. John Haggerty's laser synthesis of ceramics program and Professor Donald R. Sadoway's electroprocessing program. Advances in adaptive materials processing will contribute significantly to the efficiency of both terrestrial and extraterrestrial processing efforts.

There are numerous other examples, but we will include just one more. Seed funding provided via the materials processing research base has more recently provided an opportunity for synergistic research on laser-induced chemical vapor deposition. This program combines the laser processing expertise of Dr. John Haggerty and the fluid mechanics and heat and mass transfer modeling talent of Professor Robert Brown in a research area with potential space applications.

Center research in the broader generic field of materials processing has two general features: the problems are closely related to space processing of materials and have both practical and fundamental significance. An interesting and important feature of many of the projects is that the interdisciplinary nature of the problem mandates complementary analytical modeling/experimental approaches which are best undertaken by several investigators. The NASA-sponsored, complementary projects of Professors August Witt and Robert Brown in single crystal growth are good examples. This effort requires materials scientists and mechanical engineers to establish empirical correlations and specific engineering designs, materials engineers to model the process dynamics, chemical engineers to model and specify heat and mass flow conditions, and electrical engineers to provide information processing for overall process control. The benefits of such a program include a synthesis where none existed before and an accelerated rate of science and technology development. This particular single crystal growth program has been officially recognized by NASA for its outstanding success in space experiments. Future low gravity experiments are also being contemplated.

The success of low gravity experiments depends directly upon the strength of the science base of the process being studied or developed. Another NASA sponsored research program under the joint direction of Professors Flemings and Szekely has advanced our understanding of electromagnetically driven flows, undercoolings, and recalescence in levitated metal droplets. The potential significance of this work lies in the possible development of novel materials structures through undercooling and innovative electromagnetic stirring systems with a broad range of metals and materials processing applications. Most important, these ground-based experiments have led to a carefully planned space experiment, initial funding for which has been approved, involving both fluid flow and undercooling measurements.

A very important aspect of many of the Center's ongoing research projects is the increasing use of mathematical modeling techniques as a research tool. The predictive capability of these models, when tested against measurements, plays a very important role in both the planning of experimental programs and in the rational interpretation of results. It is particularly important that space experiments be based upon extensive ground-based processing experience. Mathematical models are proving to be extremely valuable in this planning process by projecting the findings of ground-based experiments to microgravity conditions. The Materials Processing Center, recognizing the importance of process modeling, is choosing this as a theme of our activities.

The specific research activities of the Center can be divided into the following classes of materials and activities:

Materials

- Metals
- Ceramics
- Polymers
- Electronic Materials
- Composites

Activities

- Mathematical and Physical Modeling
- Rapid Solidification
- Welding and Joining
- Electroprocessing
- Solidification
- Non-Destructive Evaluation
- Materials Systems Analysis

The research activities in each of these areas are presented in detail in the Materials Processing Center Annual Report and will not be discussed further here.

II. MATERIALS PROCESSING CENTER OBJECTIVES

Goals

Materials processing is the engineering field that seeks to control the structure, shape, and properties of materials in a cost effective and environmentally acceptable manner. It links basic science to societal needs and experience, Figure 1. Materials processing includes extraction, processing into bulk and/or engineering materials, fabrication, recycling, and disposal.

The major goals of the Center are to:

1. Improve the scientific base for materials processing technology, focusing resources and new efforts on currently practiced or new processes, by developing:

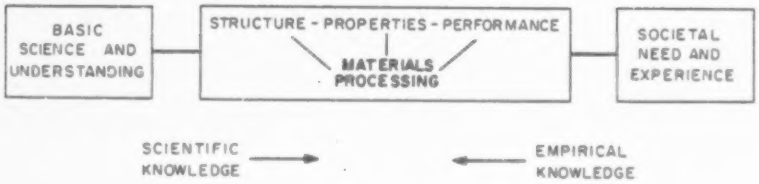
BASIC SCIENCE AND UNDERSTANDING
STRUCTURE - PROPERTIES - PERFORMANCE
MATERIALS PROCESSING
SOCIETAL NEED AND EXPERIENCE
SCIENTIFIC KNOWLEDGE
EMPIRICAL KNOWLEDGE

Figure 1. Materials Processing as part of Materials Science and Engineering.

   (a) Mathematical and physical models, including new theories;
   (b) Critical experiments using model materials systems to test the models; and
   (c) Sensing and measuring techniques yielding detailed data to confirm the models but, more significantly, also leading to the control of processes in manufacturing operations.

2. Contribute to the complex issues involved in establishing and improving industrial materials processing operations and in producing, managing, and conserving the country's national resources by:
   (a) Innovating new materials processing techniques;
   (b) Disseminating modern technology and fundamental knowledge; and
   (c) Seeking rational solutions to societal and systems problems in materials processing.

3. Develop an expanded talent base in materials processing by:
   (a) Providing research programs for graduate education;
   (b) Establishing fellowships to attract the best students to the field;
   (c) Developing post-doctorate and junior faculty positions in processing, including career development chairs;
   (d) Expanding the involvement of MIT staff and students in materials processing as an area of professional concentration;
   (e) Developing a Master's Degree program in materials processing (Materials Systems Engineering); and
   (f) Educating and motivating professionals in the field of material processing through the development of curricula and educational materials in close liaison with industry personnel.

4. Strengthen institutional relationships among M.I.T., industry, and government by providing a focal point at the common interest issues of materials processing, manufacturing, and productivity using public forums such as the Materials Processing Center (MPC)/Industry Collegium and the MPC Industrial Advisory Board.

The research activities in each of these areas are presented in detail in the Materials Processing Center Annual Report and will not be discussed further here.

Table I

1981-1983
Advisory Board for Materials Processing Center, M.I.T.

. Donald J. Blickwede
nsultant
thlehem Steel Corporation

. Kenneth J. Brondyke
rector
coa Laboratories
uminum Company of America

. Harris M. Burte
ief
etal & Ceramics Division
right Patterson Air Force Base

r. John R. Carruthers
aboratory Project Manager
olid State Laboratory
ewlett Packard Labs

r. Paul A. Fleury
irector
aterials Research Laboratory
ell Laboratories

Dr. Rodney E. Hanneman
Vice President
Corporate Research & Development
Reynolds Metals Division

Dr. Halpern*
Director
Materials Processing in Space
NASA

Mr. Frank B. Herlihy
Vice President
Group Executive-Hydraulics
Abex Corporation

Dr. John R. Hutchins, III
Vice President & Director of
Research & Development
Corning Glass Works

Dr. Anthony D. Kurtz
President
Kulite Semiconductor Products, Inc.

Dr. Horace N. Lander
Senior Vice President
Research & Development
AMAX Molybdenum Division

Dr. George Mayer
Director
Metallurgy & Materials Sci. Div.
Army Research Office

Dr. Robert Mehrabian
Director
Center for Materials Science
National Bureau of Standards

Continued...

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* NASA Representative

Mr. John H. Morison
Chairman of the Board
Hitchiner Manufacturing Co., Inc.

Dr. Richard K. Pitler
Sr. Vice President-Technical Dir.
Research Center
Allegheny Ludlum Steel Corporation

Mr. Richard F. Polich
Chairman
Tallix Incorporated

Mr. James F. Rechin
Vice President
Turbine Components Division
Equipment Group
TRW Incorporated

Mr. Robert Rowse
Vice President
High Performance Ceramics
Norton Company

Dr. Maurice E. Shank**
Director
Engineering Technology
Commercial Products Division
Pratt & Whitney Aircraft Group
United Technologies Corporation

Mr. Charles H. Smith, Jr.
Chairman of the Board
SIFCO Industries, Incorporated

Dr. M. A. Steinberg
Dirctor of Technology Applications
Lockheed Aircraft Corporation

Mr. Thomas R. Wiltse
General Manager
Central Foundry
General Motors

Dr. Edward S. Wright
Director
AMMRC

** Chairman

The Materials Processing Center/Industry Collegium

The Center took a major step forward in expanding the scope of direct interaction with industry with the initiation of the Materials Processing Center/Industry Collegium on November 1, 1981. The central goal of the Collegium is to provide a mechanism for improved interaction of Center faculty, staff, and students with industry personnel. To date, nearly 57 companies have joined or agreed to join the Collegium, Table 2, and we intend to extend this number to 100. The Collegium functions in close cooperation with M.I.T.'s Industrial Liaison Program, which has roughly 300 member companies worldwide.

Collegium services include semiannual Collegium Reports through which all unpublished papers and reports by MPC faculty and staff are made available to Collegium members. The Collegium hosts numerous short visits and tours of MPC facilities by representatives of member companies and arranges extended visits, a month to a year in duration, by member company representatives interested in direct participation in MPC research and development activities. The Collegium supports faculty and staff in the development of new curriculum and texts in materials processing, assists in the acquisition of necessary equipment, expands industry/university/government personnel interaction and exchange, and supports seed research projects.

Scholarship and fellowship programs have been established by the Industry Collegium to attract the Nation's most outstanding students from engineering, physics, and chemistry to the field. The goal is to significantly improve the talent base working on the development and economic production of sophisticated new materials and materials processes. Four undergraduates, having recently completed their junior years at other univer-

Table 2

MATERIALS PROCESSING CENTER/INDUSTRY COLLEGIUM
Membership as of September, 1983

1. Akzo
2. Alcan International Limited
3. Allegheny Ludlum Steel Corp.
4. Allied Corporation
5. Aluminum Company of America
6. Amax, Inc.
7. American Cyanamid Company
8. American Oil and Supply
9. Atlantic Richfield Company
10. Augat
11. Bethlehem Steel Corporation
12. Brown, Boveri, & Cie AG*
13. Cabot Corporation
14. Celanese Research Company*
15. Centro Sperimentale Metallurgico
16. Combustion Engineering, Inc.
17. The Continental Group, Inc.
18. Corning Glass Works
19. DuPont
20. Dow Chemical U.S.A.
21. Elf Aquitaine*
22. Enichimica
23. Exxon Res. & Eng. Company
24. General Motors Corporation
25. GKN Technology*
26. GTE Laboratories, Inc.
27. Hitachi Metals, Ltd.
28. Howmet Turbine Components Corp.
29. IBM
30. IHI Company, Limited
31. Imperial Chemical Ind., Ltd.*
32. International Harvester
33. Inter. Lead & Zinc Research Org.
34. Lockheed*
35. Mead
36. Nerco, Inc.*
37. Nippon Mining Company, Ltd.
38. Nippon Steel Corporation
39. NKK*
40. Norton Company
41. Nyacol
42. PPG Industries, Inc.
43. Reynolds Metals Company
44. Compagnie de Saint-Gobain
45. Shell Internationale
46. Solvay & Cie*
47. Sprague
48. Steel Authority of India, Ltd.
49. TAM
50. Tektronix, Inc.
51. Toyo Kohan Company, Ltd.
52. Toyota Motor Company, Ltd.
53. TRW, Inc.
54. U.S. Steel Corporation
55. United Technologies Corp.*
56. Unitrode
57. Westinghouse

*Have agreed to join or are expected to join.

sities in physics or chemistry, participated in last summer's scholarship program. Ten full-year fellowships have been offered to first-year graduate students for the coming academic year in the departments of Materials Science and Engineering, Electrical Engineering/Computer Science, Mechanical Engineering, and Chemical Engineering.

Another major Collegium activity is the sponsorship of workshops. Three have been held to date dealing with: (1) Rapid Solidificiation Processing; (2) Mathematical and Physical Modeling of Materials Processes; and (3) Ceramic Powder Processing: Is There a Better Way? The last workshop attracted over 150 participants from 60 companies and 6 government agencies. Our next workshop is planned for October 4 and 5 and will deal with "Recent Advances in Welding and Joining." Also planned this coming year is a joint NASA/MPC workshop on "The Effects of Convection in Materials Processing" which will lay out the scientific aspects of terrestrial and extra-terrestrial processing effects and workshops on "Electronic Materials Processing" and "Polymer Processing."

One measure of the effectiveness of MPC/industry interaction is industry's direct support of faculty positions. A generous gift from Toyota Motor Company to MIT has established the endowed Toyota Professorship of Materials Processing, which was awarded to the Center founder and first Director, Professor M. C. Flemings. The new Director of the Center, Professor H. K. Bowen, has been awarded the endowed Ford Professorship of Engineering. In addition, Norton Company has provided funds for three years for an Assistant Professor of Materials Processing, Professor G. L. Kalonji. We have also recently completed the three-year support of Corning Glassworks for an Assistant Professor of Ceramics Processing, Professor A. Bleier. Additional support of this type is anticipated.

The commitment of the MPC to education goes beyond the traditional role. The MPC is assisting in the planning and development of a new joint engineering/management Master's Degree program at MIT in Manufacturing Systems Engineering. This is part of an effort to establish an innovative academic program which will consider integrated manufacturing systems issues. This initiative is particularly important in high technology systems, components, and sub-assemblies, which are becoming more process sensitive. As a separate item, MPC faculty and staff have developed a specific two-week summer course in Applied Materials Technology for middle-level managers of manufacturing, design, and development engineering for the purpose of upgrading processing knowledge and skills. A similar program was organized for NASA's astronauts, with MPC faculty and staff traveling to the Johnson Space Center to conduct classes in various aspects of materials processing. These astronauts have visited M.I.T. on several occasions to gain first-hand knowledge and experience with various materials processes. This type of interaction is encouraged and will be expanded.

Consortia

Over the past 3-1/2 years, there have been several research consortia in topical areas. In these consortia, companies and, in some cases, government agencies or labs have combined financial resources to sponsor a generic research program. Two separate consortia in ceramics processing, one dealing with capacitors and another with silicon chip packaging, had a total of 10 company sponsors. These have now been replaced by a broader program which will have participants from over 30 companies and government laboratories. The approach is to study fundamental concepts which each organization can adapt to its own proprietary technology. The most important and effective mode of information transfer is through residence programs whereby company scientists and engineers join the campus research group for a period of time and thus understand the processing details long before reports are published. In some instances they have become co-authors of published papers.

Another consortium in materials systems analysis is currently studying the future of materials in the automobile industry. With six participaing companies from the United States, Europe, and Japan, this consortia is primarily concerned with the dynamics of current and future materials utilization and substitution in worldwide automotive application.

One consequence of the Collegium and these Research Consortia is industry's request for our graduates. We have requests for about three times more research and development engineers and scientists than we produce.

IV. RECOMMENDATIONS

In light of the above discussion, it is clear that I strongly support the concept of federally supported, focused basic research within a university Center of Excellence in support of industrial innovation and new process and product development. Such government-university-industry collaboration, if properly orchestrated, offers many benefits and opportunities for all parties concerned.

In the absence of a technology push on the part of a special industrial interest group, it is incumbent upon the government to provide a technology pull when a need or opportunity is perceived. The goal, in this case, is to support basic research which extends the science base while educating and training individuals who will have an exposure to industry and an interest in technology transfer and the innovation process.

The support of focused basic research within a university center provides unique benefits and opportunities. However, such support must first be adequate to sustain a core of highly qualified faculty. This critical mass is necessary to attract first rate students and research staff. Once this infrastructure is in place, high quality, long term research programs can be established. This faculty and research base provides an immediate step function with respect to the number of people being trained and entering the field of interest. However, intimate university contact with companies in the field of interest is critical to insure timely technology transfer.

Direct university-industry contact and interaction is extremely difficult to initiate and maintain. It is both a time consuming and expensive proposition. Massachusetts Institute of Technology has a long history of successful interaction with industry which is founded upon the efforts of the Industrial Liaison Program and Resource Development Office. These internal organizations employ an extensive, highly professional staff which has contributed substantially to the success of our Industry Collegium and consortia. These models for industrial interaction exist and can be duplicated if a commitment to such programs exists.

The direct interaction with industry personnel, which liaision-type programs provide, promotes the technology transfer and synergism upon which such assistance to other universities, industries, and governments at home and around the world.

Mr. **Volkmer**. All right. Thank you very much, Professor Flemings.

We will now proceed with Dr. Saville.

Dr. **Saville**. Yes; I have some remarks which I'd like to read.

According to the charter for these hearings, we're met today to discuss recommendations regarding university research centers. More specifically, a center for basic research into the separation and development of biological materials with special attention to the utilization of microgravity environments.

Part of the impetus derives from recent experiments by the McDonnell Douglas/Johnson & Johnson group employing electrophoretic techniques aboard the space shuttle. Another factor is the large number of new discoveries in the life sciences involving the synthesis of materials holding great promise for the treatment of human disease and the improvement of technology in general. As preparation for the discussion, several points need consideration.

Most of these discoveries have been in areas of basic research and the products are still under development. A common misconception is that current technology is sufficient for the task of production and purification in economically viable quantities and all that is lacking is money. If this is not obviously untrue, it is demonstrably misleading.

This committee hardly needs a lecture on the degree to which these new discoveries are likely to influence mankind, but we would all do well to keep in mind the difficulties involved in translating basic research discoveries into practical technologies. I submit that the problems involved in separating biological materials in the amounts and purity required are far from solved and, in many cases, I doubt whether the problems have been defined in anything like scientific terms.

The second point concerns motivation for research. Industrial research is, and must be, responsive to the need for financial profit. This leads to proprietary control of information which tends to thwart the open exchange of ideas that characterizes the pursuit of knowledge in a university. Praiseworthy as the McDonnell Douglas efforts are, we all await publication of results in the refereed scientific literature. Until such time as the results can be scrutinized and examined by the scientific community at large, they do little to advance general scientific knowledge.

Lastly, I want to contrast the nature of the research on what has been termed space processing with other research utilizing the space environment. The collection of scientists and engineers engaged in the research on materials is extremely diverse, and even specialized groupings focused on crystal growth or biological separations will span a wide spectrum of motivations and attitudes. Most are skeptical about the degree to which microgravity experiments will be useful for scientific or technological purposes. This attitude appears in sharp contrast to what I believe to be the attitude among, say, astronomers. There a great deal of effort has been spent circumventing or overcoming the effects of the Earth's atmosphere on astronomical observations. Although there may be questions about the methodology, very few doubt the advantages of observing the universe from an orbiting platform free of atmospheric interference.

These points argue in favor of a university center focused on separation and development of biological materials. Such a center could provide a focal point for work that begins where molecular biology and genetic engineering leave off, carry out research needed to ascertain the extent to which microgravity can be used to facilitate the various processes, and help establish the scientific credibility of the program.

The mission of the center should be the study of biological separations processes with emphasis on developing basic scientific data regarding the degree to which operation in a reduced gravity environment could improve specific processes. Two sorts of improvements are possible. First, buoyancy and sedimentation, which strongly influence separations processes such as electrophoresis, are much weaker in a microgravity environment. Thus, one might expect better resolution or higher throughput by operating separations machines in an orbiting laboratory. Here, however, we ought to be looking toward doing things that cannot be done terrestrially rather than incremental advantages. Second, experiments in a low-g environment will allow us to test and refine theoretical models of processes where flow patterns are strongly complicated by gravitational effects. Such refinements may lead to improvements in devices intended for terrestrial operation.

The center should be structured to carry out its mission by performing research and teaching functions. In addition to a small permanent staff, many of whom must hold professorships in the parent institution, provision should be made for a research staff of predoctoral and postdoctoral scientists and engineers. The center should attract people on sabbatical leave from industrial research laboratories or other universities with support from the center and the individual's own research program. Part of the teaching function should be accomplished by offering formal courses as part of the university's graduate curriculum.

The center must function within the context of programs funded by other Federal agencies as well as industry, so it will be important to establish a formal advisory body to help guide the center. At the outset, funding will come from the NASA program in microgravity science, but with a successful program, the center can be expected to gain support from other Government agencies and industry.

Finally, with the relatively small budget, the activities of the center should be focused initially on a few separations techniques and other research should continue to be supported by NASA outside the activities of the center. In addition to an annual budget for research, a large initial expenditure will be required to set up the laboratory. Because of the new and relatively unique nature of the center's acitvities, ample time should be allowed for fulfillment of the center's charter. At least 2 years will be required to bring the organization up to speed and several more years may be necessary to accomplish its mission.

I believe that a university center structured along these lines can serve a useful purpose and help ascertain the degree to which a microgravity environment can facilitate the separation and development of biological materials. Thank you.

[Answers to questions asked of Dr. Saville follow:]

Princeton University
SCHOOL OF ENGINEERING AND APPLIED SCIENCE
DEPARTMENT OF CHEMICAL ENGINEERING
THE ENGINEERING QUADRANGLE
PRINCETON, NEW JERSEY 08544

October 7, 1983

The Hon. H. L. Volkmer
Chairman, Subcommittee on
Space Science & Applications
Suite 2321, Rayburn House Office Bldg.
Washington, DC 20515

Dear Mr. Volkmer:

In response to your queries of September 15 the following comments are offered.

Q. Given the necessary limitations in funding, what should be the technical focus for the center? How should these priorities be established and who should establish them?

A. The technical focus of the center should be on fundamental aspects of separations techniques rather than the synthesis of biologically interesting materials. Since the objectives are to establish the role of gravitational forces in separations processes for biological materials, to ascertain the degree to which a microgravity environment might facilitate matters, and to develop improved processes for terrestrial or microgravity operation, the technical focus should be on schemes where gravity plays an obvious role, electrophoretic processes for example rather than, say, chromatography. On the other hand it will be necessary to be fully informed about all manner of processes if meaningful comparisons are to be drawn and sound recommendations made.

Although the general direction of the center should be established by the charter for the center, priorities will change as the field evolves and the center begins to establish itself. Thus, priorities should be established by the director, in close consultation with the advisory board, who must recognize that the center's focus is basic research in separations not the production of a specific biochemical.

Q. What would be an adequate level of funding for continuous operation of the Center? How could additional non-NASA funding be secured?

A. At the outset, not less tha $3 million/year. This is based on the expectation that there will be at least six full time senior level scientists active and each individual's program will cost $500K/year to support the associated staff members and specific research projects. Additional (non-NASA) funding should be sought through the submission of research proposals to other government agencies (NSF and NIH for example) and by forming industrial participation groups along the lines employed by the MIT Materials Research Center.

Q. To what extent should theoretical modelling be a part of the Center's activities? How can we ensure that the theoretical effort supports experimental activities at the Center?

A. Theoretical modelling should be an integral part of the Center's activities. The phenomena themselves are complicated and attempts at interpretation, prediction, comparison and the like are bound to founder without a detailed theory that can be used as a framework for understanding. There are a myriad of interacting processes to be sorted out, fluid motion, chemical and biological phenomena and it is therefore expedient to bring many tools to bear on the problem. Theoretical (mathematical) modelling is likely to be just as important as experimental studies, neither will be a substitute for good ideas, insight and inspiration.

The theoretical and experimental efforts ought to support one another. It should be the aim of the theoretical section to help explain, codify, interpret and predict aspects of the work of the experimental section. Neither will be able to function in a way that will accomplish the Center's goals by working alone and the only way to ensure cooperation is by choosing the mix of research scientists carefully, starting with the Director, who must appreciate the contributions each group can make to the success of the project.

Q. How can we promote international participation in the Center's activities without, at the same time, introducing undesirable technology transfer?

A. A response to this question is likely to hinge on what is meant by "technology" and "undesirable". One way is to avoid developing specific sorts of devices, designed to accomplish a specific task. Instead the Center ought to focus on fundamentals and leave the task of perfecting devices to the industrial sector of the nation.

Sincerely,

Dudley Saville

D. A. Saville
Professor of Chemical Engineering

Mr. VOLKMER. Thank you very much.

Professor Bier.

Dr. BIER. Thank you, Mr. Chairman.

I greatly appreciate the honor and privilege of testifying in front of this distinguished subcommittee. The present hearings are held under the influence of the McDonnell Douglas/Johnson & Johnson space experiments.

Whether or not electophoresis survives as a space activity, other processes are likely to follow. McDonnell Douglas deserves recognition for being the first to back this vision with their own hard cash.

At present, I wish to voice my most enthusiastic support for the proposed center. The center will, I believe, advance biotechnology in general and will be essential for the NASA program itself. To support this contention, I would like to address the following topics:

One, is there any need for improved purification methods; two, the role of electrophoresis; three, NASA's activities in space electrophoresis; four, the proposed center itself.

The first question is the easiest to answer with the most emphatic affirmative. The revolutionary advances in genetic engineering have rendered possible the production of innumerable new biologics, previously available in minutest quantities only. It will suffice to say that these new biologics have the requisite astronomically high prices, in the millions of dollars per pound, to be amenable to space processing. Moreover, purification is already a major bottleneck in their production. We are only at the threshold of this revolution in biotechnology, which will require ever-increasing sophistication in the art of separation and development. Thus, the NASA program is the unwitting beneficiary of these new developments.

Now, as to electrophoresis. It is practiced on a worldwide basis in literally thousands of laboratories. However, most of this work is restricted to analytical applications.

In the preparative area, only three methods are available. The McDonnell Douglas continuous flow apparatus, where the most striking contribution of this is their claim of improved increased throughput. The second apparatus available is—was designed by Dr. Thompson at the Harwell Atomic Energy Establishment in England. It is an impressive machine with a large throughput.

The third machine is our own machine for recycling isoelectric focusing developed under NASA's sponsorship. The apparatus was first proposed for operation in microgravity, but it proved to be quite effective also in its ground-based usage. Schering Corp., Ely Lilly and Ionics, Inc., have already acquired this apparatus. We anticipate that in space, some of its present limitations may be overcome. This will be tested in a space experiment scheduled to fly aboard the *STS 11,* in early 1984.

Unfortunately, there has been as yet no opportunity to compare the resolving power of these three instruments, which is a crucial factor. The Harwell machine and our own apparatus have adequate throughputs. In space operation, our objective is increased resolution, while McDonnell Douglas seeks higher throughputs. In general, the three instruments should be viewed as complementary rather than competitive and should contribute to the general acceptance of electrophoresis as a processing method.

My third topic is NASA's program on electrophoresis in space. At the inception of its MPS program, NASA has correctly identified electrophoresis as being singularly affected by gravity. In view of the limited flight opportunities and lack of unanimous and enthusiastic support from the scientific community, NASA's subsequent approach to space processing was cautious, and the expenditures inadequate for a significant breakthrough.

Other agencies, notably the National Institutes of Health and the National Science Foundation, were even less generous. There was a general feeling among concerned scientists that these agencies were not favorably inclined toward the support of so-called methodological research in electrophoresis.

In view of this longstanding benign neglect of electrophoresis, I believe that the proposed university center for separation is long overdue.

In my written statement I proposed—I took the liberty of outlining a possible structure of such a center. Essential is the Scientific Board of Advisors to comprise leading scientists from industry and academia. They have to provide overall guidance to the activities of the center, which should be the furtherance of NASA's objectives in space and the general advancement of purification technologies.

The center should promote two objectives. It should become a national resource for education and research in purification technology. Thus, it should offer sabbaticals to researchers from industry and academia, have graduate and undergraduate study programs, organize seminars, meetings and workshops, perform economic analysis, and provide the requisite laboratory facilities and technical staff support.

The second objective should be to acquire academic excellence in research. This research should at present be not only focused on electrophoresis, as this is now the primary objective of NASA's space bioprocessing. As NASA's interests broaden, so should the center's activities; or as the center's activities broaden, NASA may follow. Research should be directed toward furtherance of better theoretical understanding of microgravity processes, study of special applications, and development of new instrumentation.

To accomplish these objectives, a critical mass is essential. Best available talent should be recruited. In addition, the support of a large body of scientists involved in peripheral aspects of biotechnology is indispensable. Thus, only a university setting is appropriate, and I feel that the allocated funds of $2 million are barely sufficient for a single center.

The startup funding of the center will come from NASA, or it should come from NASA. This should shortly be complemented by support from the pharmaceutical industry as the value of the center becomes appreciated. Eventually, the umbilical cord to NASA should be severed and the center should compete on the open marketplace for all available funding from industry, NASA and other Government granting agencies.

Thank you, Mr. Chairman.

[The prepared statement, plus answers to questions asked of Dr. Bier, follow:]

TESTIMONY OF

MILAN BIER - UNIVERSITY OF ARIZONA

before the

SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

September 15, 1983

It is a great personal honor and privilege to testify in front of this distinguished Subcommittee. The opportunity to do so is particularly appreciated in view of the successful McDonnell Douglas/Johnson & Johnson space experiments. With the brashness characteristic of the best of American enterprise, they have suddenly thrust us in a radically new era of industrialization of space. New vistas and potentials have been opened, for which we scientists, in our more cautious ways, may not have been prepared. The impact of their experiments on future technology may prove to be overwhelming for they were the first to demonstrate the feasibility of establishing manufacturing processes in outer space. Whether or not electrophoresis survives as a space activity, other processes will certainly follow. McDonnell Douglas and Johnson & Johnson deserve praise and recognition for being the first to back this vision with their own hard cash.

This breakthrough in space processing imposes on concerned scientists and technologists the imperative to review and appraise its impact. I had the privilege to submit in 1975 a written statement on the future of space electrophoresis to this Subcommittee, then chaired by Hon. Don

Fuqua and in 1978 to the parent Committee, chaired by Hon. Olin E. Teague. These were optimistic appraisals, and I feel gratified to find that my optimism was justified.

At the present hearing I wish to support most enthusiastically the establishment of the proposed University Center for Separation and Purification. Having spent most of my professional life in this field, I must admit to a parochial interest in such a Center. Beyond that, I am certain that the Center will contribute substantially to the general advancement of biotechnology, even if one disregards the NASA program. For the success of the Materials Processing in Space program, however, the Center is essential.

In support of this contention, I will address the following points:

The need for improved purification methods.

The role of electrophoresis.

NASA's Program in space electrophoresis. Support from other granting agencies.

The proposed University Center for Separation and Purification.

A. Purification Technology

We are in the midst of a revolution in applied biology due to advances in genetic engineering and the allied fields of monoclonal antibodies, synthesis or isolation of individual genes and solid phase synthesis of peptide hormones. The social and economic impacts of this new biotechnology have been amply covered in the scientific as well as lay press. An authoritative review has been prepared by the Office of Technology Assessment, U.S. Congress, under the title: Impacts of Applied Genetics - Microorganisms, Plants, and Animals.

These technologies have rendered possible the production of virtually unlimited quantities of important new biologics, which were previously available only in minute quantities. Interferon, human growth hormone, a foot and mouth disease vaccine, are but a few of such pharmaceuticals which can be cited as examples.

For the purpose of the present hearings, it should be emphasized that these biologics are often first obtained in the form of crude extracts, heavily contaminated by extraneous matter. For example, in recombinant DNA, a gene, coding for the desired pharmaceutical, is implanted into bacteria or yeast, thereby 'engineering' the microorganism to produce a protein which it normally does not synthesize. The new protein has to be separated from the myriad of other proteins native to the microorganism. Similarly, monoclonal antibodies are produced by hybrid cells, obtained through the fusion of an antibody-producing lymphocyte and a cancerous cell. It is the cancerous moiety which confers to the hybrid its ability to rapidly reproduce. Again, the monoclonal antibodies need to be separated from the other proteins of the hybrid cell. The magnitude of the problem can be best visualized if one realizes that the host cells, the modified microorganism or the hybrid, may contain well over 5,000 different proteins, only one of which is the desired active principle.

The utmost in purity is essential for any of these products to be administered to a patient. Present purification technology is as much an art as a science, and is often a major bottleneck in production. It mostly involves a series of purification steps, artfully sequenced until the required purity is obtained. Chromatography is the main workhorse, and the whole process is costly and inefficient - at times only a minute fraction of total material synthesized is obtained in purified form.

We are only at the beginning of this revolution in biology. Modified plants and animals are on the horizon. Interferon, monoclonal antibodies and other such biologics may be our next weapons against cancer. Eventually, we will even learn how to eliminate some pernicious genetic diseases in man himself through gene implantation and gene therapy. It is indisputable that these advances will require ever increasing sophistication in the art of separation and purification. Thus, NASA's program is the unwitting beneficiary of these new developments and may become of crucial importance for future biotechnology.

Many of the biologics are in a price range which could justify space processing. Their unit value may exceed millions or tens of millions of dollars per kilogram. On the other hand, total demand may be only a few kilograms annually. Any new separation process has to have high resolution and high yield, that is, isolate the desired product in high purity and with minimal losses.

B. Electrophoresis

Electrophoresis is a most elegant technique for the separation of complex mixtures of biological origin. Because of its unique usefulness, a great variety of instruments have been developed and these are used in literally thousands of laboratories the world over. Most of this usage, however, is confined to analytical applications only, and is of little relevance to the task at hand, namely the purification of pharmaceuticals on an industrial scale.

At present, a paradoxical situation prevails. Analytical electrophoresis, in particular the so-called two-dimensional electrophoresis, offers the highest resolution of any separative technique and is routinely utilized for quality control in the production of biologicals. Nevertheless, no form of electrophoresis is routinely utilized in production of these compounds. In the past the requisite instruments may have been missing, but this is no longer true. Nevertheless, it should be emphasized that no single technique, chromatographic or electrophoretic, can be considered as a panacea for all separation problems. Instead, they all should be considered as components of an increasingly more complex armamentarium of purification methods. Thus, any electrophoretic apparatus on its own is unlikely to suffice for the purification of any product of genetic engineering, but can only be integrated as one step in an overall production scheme.

Three instruments are presently available for large scale processing:

1. The McDonnell Douglas continuous flow electrophoresis apparatus. This type of instrument was pioneered by Prof. Hannig in Germany. In ground-based operation, Hannig's instruments were characterized by rather limited resolution and throughput. Thus, it was rarely used for separation of proteins, its main application being in research with living cells.

The McDonnell Douglas apparatus was superbly engineered and performed flawlessly in the microgravity environment. This was certainly no mean achievement. Most important is their claim of greatly increased throughput. Personally, I am most anxious to see a far more detailed documentation of the design and performance of their apparatus, kept at present proprietary for obvious reasons.

2. For the past ten to fifteen years, Dr. Thompson at the Harwell Atomic Energy Establishment in England has been developing a centrifugal electrophoresis apparatus of a radically new design, first proposed by Prof. Philpot, some 40 years ago. It is an impressive machine, with

large throughputs, up to 100 grams of protein per hour. It has not been available until most recently, and is now marketed under the tradename BIOSTREAM by John Brown Limited of Portsmouth, U.K.

3. The Recycling Isoelectric Focusing Apparatus (RIEF), developed in my laboratory under NASA's sponsorship. The RIEF was first proposed for operation in microgravity, but to my great surprise, it proved to be quite effective in its ground-based operation. Schering Corporation and Ely Lilly Laboratories, two leading companies in the genetic engineering field, as well as Ionics, Inc., an engineering company, have already acquired the apparatus. We anticipate that its resolution may be improved in microgravity. This will be tested in a space experiment, scheduled to fly aboard the STS 11, in early 1984. This experiment is aimed at scientific information and is not a prototype of our separating device.

A brief comparison of these instruments may be in order. The Harwell and the RIEF have adequate capacities. The expected advantage of the operation of the RIEF in space is only increased resolution, while McDonnell Douglas aims at higher throughputs. Unfortunately, there was as yet no opportunity to compare directly the resolving power of the three instruments, which is a crucial factor. Isoelectric focusing is characterized by very high resolution, and I would expect that we have some advantages in this regard. On the other hand, focusing imposes more drastic conditions on treated materials than continuous flow electrophoresis. Thus, the McDonnell Douglas apparatus is gentler and is applicable to a wider range of products. Of specific important, it can separate living cells, which cannot be treated in the RIEF. In general, I expect that each of the three instruments will find its own niche, and that they should be viewed as complementary rather than competitive.

C. NASA's Program and Support from other Agencies

At the inception of its Materials Processing in Space (MPS) program, NASA correctly identified electrophoresis as being a process singularly affected by gravity. Until the advent of the Shuttle, the opportunities for experimentation in space were most limited and consequently, NASA's approach to the MPS program was most cautious. Without being privy to NASA's budget, I rather suspect that their expenditures for electrophoresis were of the order of one million dollars annually, a sum woefully inadequate for a significant breakthrough. In all sincerity, the scientific community must share the responsibility: it lacked unanimity and gave conflicting advice. It is to NASA's credit that it persisted with the program, in spite of the many difficulties and slow start.

It is also significant that NASA was the first U.S. granting agency to give substantial direct support for electrophoresis. Other agencies, notably the National Institutes of Health and the National Science Foundation, may have been less generous. There was a general feeling in the community of separation scientists that these agencies were not favorably inclined towards the support of 'methodological' research in electrophoresis. If electrophoresis has thrived in spite of this, it is because much of the research in this field was incidental to other projects, directed towards specific diseases or other biomedical topics. I would hazard to guess that some researchers, interested in more fundamental problems of electrophoresis, have actually learned to camouflage their true interests and couch their requests for funds in a context of other objectives deemed more appealing to the granting agencies.

D. The Proposed University Center for Separation and Purification

The mission of the proposed Center for Separation and Purification should be the furtherance of NASA's objectives for bioprocessing in space. Of all purification methods, only electrophoresis is presently clearly identified as benefiting from a microgravity environment and electrophoresis should be at the core of the Center's activities. Moreover, the budgeted sum of two million dollars is inadequate for any broader consideration of other separating principles. Looking, however, beyond the Shuttle towards the possible development of a permanent orbiting space station, the scope of bioprocessing activities is sure to increase. The Center should be at the forefront of such an expansion.

With this premise, I feel, nevertheless, that the functions of the Center will not be narrowly restricted to electrophoresis alone. The Center should have two major tasks:

1. It should become a unique national Center for Research in separation technology. This research activity should be limited to processes which may benefit from microgravity, at present this being electrophoresis only. In view of the past benign neglect of electrophoresis on the hands of various granting agencies, the proposed Center is long overdue. In the mind of most researchers, the notion of electrophoresis is identified with its analytical applications on the minutest scale. It will require a major effort to reverse this limited view and get the scientific and industrial communities to accept electrophoresis for what it is: a powerful processing tool capable of widespread industrial usage.

2. The Center should also become a National Resource for the comparative evaluation of diverse purification processes. This aspect

of the Center's function can not and should not be restricted to electrophoresis only. The Center should develop competence in a representative cross-section of other advanced separation technologies, notably various chromatographic techniques. Only in this manner can it serve the industrial community, which is not interested in space only, but needs objective evaluation of alternate technologies for a specific purification task.

There are other types of resource activities that the Center could provide. It is quite difficult to obtain information on some rather elementary economic considerations impinging upon the development of new pharmaceuticals, such as relationships between production processes, purification costs, sales price, and usage patterns. An economic analysis of alternate purification processes, along with projected needs for specific products would be of great help in the furtherance of NASA's objectives.

It is important that the Center not become a handmaiden of either the NASA program or the pharmaceutical industry. Instead, it should strive for academic excellence. This requires a staff of leading separation scientists, interaction with a large body of experts in the most diverse areas of biotechnology, and a graduate and undergraduate teaching program. The equivalent of sabbaticals should be available to scientists from industry and academia. Other educational activities should include the organization of scientific meetings, seminars, workshops, etc.

Based on these premises, I took the liberty of outlining on the enclosed diagram a possible scheme for the organization of such a Center. The first step should certainly be the establishment of the Science Advisory Board, comprising leading scientists from industry and academia. The Board has to provide an overall guidance to the Center's activities and its members should be available for individual consultation.

Equal emphasis is placed on the resource and research activities of the Center. Bridging the two is the contemplated economic analysis activity, as outlined above. An important task of both groups should be the fostering of industrial awareness of the potential of NASA's Materials Processing in Space program for biologics and the promotion of the unique opportunities for space research in biotechnology. This should be done by establishing collaborative interaction with the pharmaceutical industry, maintainance of a liaison with various regulatory and granting agencies, and organization of a visiting scientists exchange program.

The engineering group should provide support to in-house research activities. It should interact with NASA and its contractors in the design and construction of flight hardware as well as developing new concepts in biotechnology instrumentation.

The analytical group should be responsible for the maintenance of a wide array of instrumentation and provide necessary services to the research staff. In addition, it should provide specialized analytical services to the pharmaceutical industry on a fee basis.

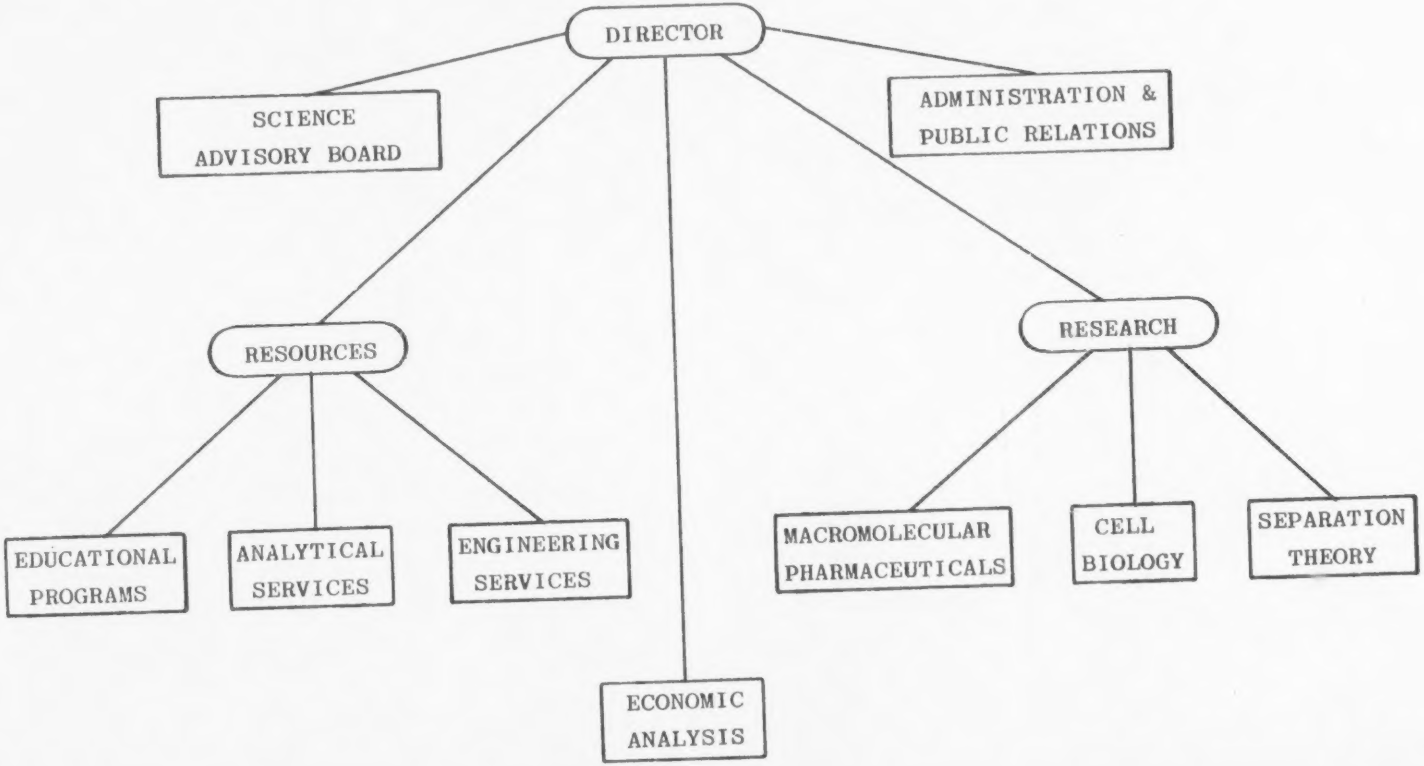
As part of its research function, the Center should endeavor to establish an environment conducive to creative research. This is always a difficult task for which a critical mass is essential. A core group of well-established scientists, the recruitment of promising young scientists, and reliance on existing University researchers, even if active in peripheral areas, are three components of this critical mass.

Our understanding of separation processes is still rather empirical and lacks a rigorous theoretical basis. This is particularly true of electrophoresis, which historically was mainly in the hands of experimentalists. It has not attracted the attention of the engineering profession, as it was not considered to be amenable to large scale processing. Moreover, it is often quite difficult for experimenters to communicate effectively with theoreticians. In our own work, we were very fortunate to have established a productive collaboration with Prof. Dudley Saville. As a result, we were able to place strong emphasis on theoretical modeling of the electrophoretic separation processes. I strongly recommend that this direction not only be maintained but greatly increased.

The Center's initial funding will have to come from NASA's resources. It is quite certain that this will be gradually complemented by contributions from the pharmaceutical industry as they come to appreciate its value. It may be unrealistic to expect that industry will ever assume all its support, as experience has shown that most research establishments have to rely on Government's support. An example in point is the Southern Research Institute in Birmingham, Alabama, originally established to foster technological development in its geographic area. At present most of its support comes from Government grants. Thus, in the future, the new Center will have to become independent of sole support by NASA and compete on the open marketplace for all available funds, from industry, NASA and other Government agencies.

SUGGESTED ORGANIZATION

CENTER FOR SEPARATION SCIENCE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SEP 26

September 23, 1983

The Honorable Harold L. Volkmer
Chairman, Subcommittee on
Space Science & Applications
U. S. House of Representatives
Suite 2321 Rayburn House Office Building
Washington, D.C. 20515

Dear Mr. Volkmer:

Many thanks for your kind letter of September 15th. It was an honor to testify in front of your distinguished Subcommittee and a rare pleasure to meet you personally.

In reply to your additional questions:

1. The technical focus of the Center should be the study of those phenomena which may best further NASA's objectives of exploitation of space for advancement of biotechnology. At present, electrophoresis is the only technique clearly identified as benefiting from reduced gravity. Thus, the primary purpose of the Center should be the advancement of electrophoresis. Moreover, the entire field of Separation Science is far too broad to be encompassed within the limits of available funding.

In the future, once the Center is established, I envision a symbiosis between NASA's activities and that of the Center: both groups should endeavor to broaden the scope of their activities to other areas of biotechnology which may benefit from microgravity. A healthy competition may result, wherein the Center may assume a scientific lead in this search, NASA assuming a more programmatic role.

The overall priorities and the mission of the Center should be established by NASA in its Request for Proposals, on the basis of extensive consultations with their intra- and extra-mural experts. Thereupon, the guidance of the Center should be in the hands of its Scientific Advisory Board and the Scientific Director, its funding and performance being subject to yearly reviews by NASA.

2. To adequately fulfill its mission, the Center should have a core group of 4 to 5 senior researchers, with a rank of full or associate Professor. With the usual backing of technical, engineering and administrative support, a total staff of about 25 can be assumed. This is to be complemented by students, postdoctoral fellows and visiting scientists. This would constitute the critical mass sufficient to attract the research and industrial communities to make the fullest use of the Center.

This leads to an estimated budget for personnel of about $800,000. Usual operational expenses are of the order of 25% of the total budget, and University's Overhead (negotiated indirect expenses) run another 40-50%. Thus, the total budget may be of the order of $1,500,000 to 1,800,000.

3. Separation science in general, and electrophoresis in particular, has evolved largely on an empirical, experimental basis. A thorough physico-chemical understanding of the processes can only be achieved as a result of theoretical studies, including computer modeling of the processes. Such studies assume special importance when one considers the complicating feature of microgravity. Essentially, mathematical studies are often cheaper then experimental work, and of greater predictive value.

Your question also addresses a second point, the communication between theoreticians and experimentalists. This is often difficult to establish, particularly if the theoreticians and experimentalists are physically located in different Departments. It is one of the virtues of a dedicated Center that it can bring these two groups into an intimate cooperation.

4. By their very nature, Universities consider one of their primary tasks to be the propagation and diffusion of scientific knowledge. Thus, most scientists are prone to attend international scientific meetings and there are certainly no national boundaries to their scientific publications. Pharmaceutical industry is also international in scope. I see, therefore, no meaningful way in which technological transfer can be prevented or minimized. The only limitation in this regard is the unique technology in the hands of NASA, i.e., its orbiting spacecraft.

I am delighted to have been of service to your inquiries.

Sincerely,

Milan Bier

Mr. **Volkmer**. Thank you very much, Professor Bier.

I want to thank all the panel for the statements.

We will now proceed with questions, and I'll first recognize the gentleman from Pennsylvania, Mr. Walker.

Mr. **Walker**. Thank you very much, Mr. Chairman.

I'm sorry I can't be more a part of the hearings. I'm over next door with the Clinch breeder reactor today. So I appreciate the gentleman yielding to me.

Dr. Stucki, I have a question about where we might be going in the field of commercialization of a lot of the materials processing work in outer space. Now, I'd like to get on the record some idea where we might be a few years from now in terms of commercial application of the research work that we propose to start here. Could you give us some idea of—of what products Americans might be using in years ahead as a result of commercial activities in materials processing in outer space?

Dr. **Stucki**. I'm not qualified to say that such products will inevitably derive from materials processing in space. But I can tell you the kinds of products that might benefit from materials processing in space.

Mr. **Walker**. All right.

Dr. **Stucki**. And these would be, in my opinion, the products of biological origin that are—or similar to products of biological origin that are large complex molecules. And this is the sort of thing that many of us in the industry are concentrating on today, albeit using different techiques, currently then materials processing in space.

Of course, I'm speaking there of large proteins, polypeptides, olinucleotides, antibodies—which, of course, are proteins—and other such substances and molecules.

The difficulties of using these molecules in therapy have been several; among them, the manufacture and the purification of such molecules. These are not the only problems, however. Certainly problems of delivery to the site of cell activity are also significant problems.

I see the future shaping up something like this with respect to that kind of molecule. I think there are going to be many of these molecules that are used to directly treat diseases. For example, almost any disease that one would see as amenable to large molecule intervention because of the involvement of large molecules in the etiology of the disease—cancer, virus disease, immune deficiency diseases, and, of course, any diseases that are protein or polypeptide hormone deficiency diseases.

Now I could also see application to situations where you would desire to carry a specific smaller chemical entity to a particular site in the body. They—what I would envision is a complex antibody seeking out a certain cell or type of cell in the body and carrying with it a specific molecule. The antibody would seek out the—the cell, would bind to the cell, and then release the—the substance at that site. This is targeted therapy.

Now, almost all diseases are possibly candidates for treatment with selected targeted therapy, everything from contraception to—to—which is not a disease, of course, but it's an application—contraception to mental diseases.

So, theoretically, the thing is unlimited. And, therefore, theoretically, processing in space could be broadly——

Mr. **Walker**. If I understand—if I understand correctly what you are saying then, that the great application will be to significantly broaden the horizons of medical treatment, that a lot of the things that we now know we can't do because we don't have the processing techniques that will be available to us with these products and, therefore, you're going to broaden the scope of medical treatment of a whole variety of diseases. Is that a——

Dr. **Stucki**. This is potentially true.

However, I would not want to be represented as saying that broadening—this broadening—this broadening is impossible without space separation techniques, because space separation techniques are only one of several approaches to isolation in manufacture that are going on.

It may be that other processes will be developed that are competitive with and perhaps even superior to separations in space. I have no way of knowing that. All I am saying is that space-age processing seems to have the capacity for contributing to the broadening of the horizons, as you suggested.

Mr. **Walker**. Thank you, Mr. Chairman.

Mr. **Volkmer**. Quite all right.

Before we recess—we have a vote on, and just went on, so we have a few minutes—before we do, I'd like to ask each panel member if they'd like to make any rebuttal to any other statement by any other panel member before we break for the vote? Does anybody wish to comment on anything else that was brought up by somebody else?

[Pause.]

If not, then we'll recess and go vote, and be back in about 10 minutes, at which time we'll continue the questioning. Thank you very much.

[Recess.]

Mr. **Volkmer**. The committee will resume its sitting.

I'd like to first make sure I have everything right in my mind after reviewing the statements of testimony this morning. I don't believe there's any disagreement that everyone on the panel supports a center as a vision. We may get into a little of some of my questions later as to what the center should actually do. But everyone agrees that we should have it and it should be located by the university; is that correct? Any disagreement with that now?

[Pause.]

All right. Now, we had one—Professor Bier, I believe, said that $2 million is barely adequate. Anyone else have to make a comment on that, because we there's a—we're going to have to be looking at that, not just this year, but next year and the following years. Anyone else wish to comment on the amount approximately that would be appropriate?

Professor Flemings, you're all—what are you—you say that MIT's up to now, 4 point?

Dr. **Flemings**. Our center is approximately $4 million a year, yes, of which 20 percent comes from NASA.

Mr. **Volkmer**. OK.

Do you envision that in the event that MIT would not be designated as the center, established someplace else, that MIT would continue on?

Dr. **Flemings**. Yes.

Mr. **Volkmer**. All right.

Dr. **Flemings**. We would be, of course, distressed at such occurrence, but it would certainly continue on.

Mr. **Volkmer**. All right.

The other question I have in structuring the center—Professor Bier has given us a suggested structure, an organizational thing. Does everyone agree that it should have an advisory board? Any disagreement on that?

Dr. **Flemings**. If I may say——

Mr. **Volkmer**. Yes.

Dr. **Flemings** [continuing]. Not only no disagreement, but an advisory board consisting of outside scientific, and in our case, business and technological individuals, has been of vital importance to the success, not only of our original mission, but of broadening our base outward to and with industry.

Mr. **Volkmer**. Now, you've had no conflict as far as—it's actually a university, and it's, let's say, responsible to the university——

Dr. **Flemings**. Yes.

Mr. **Volkmer** [continuing]. Correct?

Dr. **Flemings**. Yes.

Mr. **Volkmer**. But you have no—does the advisory board work for the head of the center?

Dr. **Flemings**. Yes.

Mr. **Volkmer**. The dean of the school, whatever it is?

Dr. **Flemings**. Both.

Mr. **Volkmer**. Both.

Dr. **Flemings**. It is an advisory—it is an advisory board in fact as well as in name. They have, of course, no direct administrative power. But their words and advice are listened to very carefully. Along with those words and advice often comes tangible assistance of one kind or another, which is also of immense value to us.

Mr. **Volkmer**. All right.

Now I want to get into a little bit perhaps maybe disagreements—maybe not, but at least we'll find out.

Now, should the center, as Professor Bier has proposed, focus on maybe one specific methodology of electrophoresis, or should the center focus on other specific technologies, or just use a broad base or basic research into all phenomena pertaining materials processing in space or microgravity science? Anyone wish to comment on that?

Dr. **Bier**. If I could, first of all, comment on that.

Mr. **Volkmer**. Yes.

Dr. **Bier**. Purification right now is a major bottleneck—a workhorse of purification are chromatographic techniques. There is a growth in the support of chromatographic techniques from the part of instrument manufacturers and widespread use in the industry of it.

Electrophoresis is the darkhorse. Also, from NASA's viewpoint, there was never any question raised whether any of the chromatographic techniques could benefit from zero gravity or microgravity. Electrophoresis was identified as possibly fulfilling this.

I must admit to my parochial interest in electrophoresis. I have worked all my professional life, 35 years, in trying to develop exactly the application that we are talking about: large-scale uses of electrophoresis.

I believe that it is cost effective to support a center on electrophoresis before we embark on very wild—very big investments of orbiting spacecraft or whatever, permanent orbiting space stations, for the McDonnell Douglas device.

It is a great device. They have done a marvelous engineering work, but the basic information is not here, whether it is really necessary to go into space or not to fulfill their objectives.

I think that it would be very cost effective for NASA to really explore in-depth electrophoresis before trying to justify an orbiting space station or whatever other next generation of equipment will be needed in order to accept the McDonnell Douglas devices.

Mr. **Volkmer**. Well, what I understand, Professor Bier, from your proposing is basically more what I would call as a layman applied research more than basic research.

Dr. **Bier**. Well, as long as we are focusing toward microgravity, it is really applied research because you are setting your objectives right from the beginning. You want to find out what is going to happen in—in microgravity.

Now, I believe that microgravity will have a future in a completely different area than electrophoresis. I think that it is a unique research tool for all kinds of aspects of biology which could greatly benefit from zero gravity. But this is a long-range objective, whereas the center will be established in 1984.

Mr. **Volkmer**. Of course, we've heard from other witnesses at prior times—the focus here seems to be on the biological significance of microgravity, but you also have the matter of crystals and glass and the matter of metal alloys, the matter of containerless fabrication, those type of things. Shouldn't this center also maybe look at those type of things?

Dr. **Bier**. I don't think that there is any cross-fertilization, or a very small at best, between the area represented by MIT and the bioprocessing. Remember, some of the phenomena—obviously fluid dynamics and some other lot, but I think that you should not really mix the two activities.

There is a wide area of application in materials processing in the traditional metallurgical semiconductor, and so on, and there is an enormously wide area of biological applications. And the two have very few common intermediates.

Mr. **Volkmer**. All right.

In other words, we shouldn't mix the work of the people that are at the center and more or less focus them on certain areas?

Dr. **Bier**. Well, I think, on two areas, if you look at the research—or three areas. If you look into the research branch of my diagram, one is micromolecular structures, which Dr. Stucki has addressed. That is the next generation. The other—the second is the theoretical studies, which Dr. Saville would emphasize. And the third is cell biology, which I think is the future trend of science in general.

Mr. **Volkmer**. All right.

Anyone else on the panel wish to comment on it so far?

No. All right.

Should the center interact with the scientific community basically through the advisory board, or how else? Because you are going to have people within the center, and you are going to have people interested outside the center that are still interested.

Dr. **Saville**. Well, I——

Mr. **Volkmer**. How would they interact.

Dr. **Saville**. I think they ought to interact in the traditional ways that science has interacted in publications, symposia, scientific meetings and the like. The center ought to facilitate these and focus some of the symposia and meetings. But I don't see a need for any exceptional ways of trying to communicate the results.

I think the advisory committee serves an important purpose, but it ought to be one designed to furnish liaison between the center and industry to a certain extent, and it ought to provide advice in the operation of the center rather than as a tool for dissemination of their results.

Mr. **Volkmer**. In this regard also, how much influence should NASA have on what goes on at the center? Anybody wish to comment on that?

Dr. **Bier**. Yes, I would like to comment on it, that the center should not become a handmaiden, either of the pharmaceutical industry or of NASA. It should further the interests of both groups, but in the academic traditional inquiry, rather than becoming an organ of NASA. If NASA wants an organ of its own for its own interests, then the center has to be established at one of the NASA centers, Marshall or Johnson or whichever.

But otherwise, this is—the main objective of the center has to be a facet of academic excellence and not a facet of NASA's immediate short-range goals.

Mr. **Volkmer**. Professor Flemings, could you comment on MIT's relationship with NASA in that regard so far?

Dr. **Flemings**. Yes. MIT's relationship with NASA has been a very fruitful one and, in my opinion, a very profitable one from both points of view in the best sense of that word.

We have what we call a materials research base funding from NASA. Or in olden times, we might have used the word "core" of funding, but a central amount of funding which is about $300,000, over which MIT has considerable discretionary powers as to exactly how that money is spent. But the money is spent in the general area of fundamental research on materials processing problems which have gravity as a component. And that, of course, is because we're looking here at broad fundamental important topics from a scientific point of view, but topics which, nonetheless, can—might ultimately have some—and we would hope ultimately would have some bearing on the zero gravity processing as well as potentially on terrestrial processing.

Beyond that $300,000 then to reach the total of our current funding of $800,000, we then have approximately $500,000 per year of funding which is in—with NASA, which is in contract areas agreed upon by individual investigators from the center and NASA relating more specifically with NASA's space—with the overall NASA's space-related processing program.

Mr. VOLKMER. Thank you.

At this time, I'll recognize the gentlemen from New Mexico. He had an opening statement. Without objection, the statement will be made a part of the record and appear right after my statement at the beginning of the meeting.

Mr. LUJAN. Let me follow up on your question, Professor Flemings.

What are some examples, generally, say, research into materials that have a gravity component to it? What sort of things, just in layman's understanding?

Dr. FLEMINGS. I'll give you two quick examples. One would be the growing of single crystals of semiconductor materials where in a terrestrial environment, in a one-g environment, there is a great deal of convection in the liquid that goes on during the growth of this important technological product. And that convection influences the resulting structure and its performance to a very great degree.

So we have programs underway studying convection, it's—in crystal growing, its effect on the electronic properties of materials and the effective gravity on that convection.

A second brief example is it is possible to take liquid metals and to cool them far below the melting point and still retain the liquid. It's a little like taking water way below the freezing point and still maintaining it liquid water, only we work with liquid metals. When one does this, one's able to obtain new structures of potential important commercial application.

Now, the point is that there are two ways that make it easy to obtain much higher undercooling than we can typically in this room, for example. One is the absence of convection and, thereby, zero gravity is a useful variable. And the other is freedom from contamination by a container. And, so, in the zero gravity of space we can levitation, melt, have no container, get more undercooling.

So the two particular progams then that I would cite as examples, one is crystal growing, convection and crystal growing, and the second is super cooling and the possibility of making new useful structures that way, as well as the base associated with both those areas.

Mr. LUJAN. Thank you. Thank you very much.

One of the things that always is in the back of my mind in the whole space program, I suppose, in all of the research that—that we do in Government, the end use of whatever products come out is really what we're—what we're striving for. All of the research and everything that we do is so that will benefit mankind somehow—in new materials or new products or whatever.

That leads me to at least theoretically believe that one of these days NASA ought to turn over—you know, we're in the commercialization of satellites, we'll be looking at commercialization of the shuttle even, you know, from a trucking company or whatever. And I'm wondering about setting up this university center. I support it. I think that that's a way to go about it.

But wouldn't companies, since they're the ones that are going to benefit directly, be willing to fund such a center? I know they do it at MIT in conjunction with—well, you just mentioned you have the $300,000 basic grant and they help you up to the $800,000. I assume there's some private industry contributions. Wouldn't they be willing to—to fund this—this whole thing because each one is looking for a particular—for a particular process rather than Uncle picking up the tab?

Dr. FLEMINGS. I could respond briefly in terms of what we do in my center, if you wish. Then I would prefer to have one of my colleagues who is in this particular technical area make some more direct comment.

My brief comment, based on my experience in the area of work that our materials-processing center is in, would be the following, and that is in this broad generic area of materials processing, there are many areas where companies will—will give us money, many types of research programs that they will sponsor.

There are many problems in dealing with industry which MIT has had to spend, and we in the center have had to spend, a great deal of time sorting out. But I can tell you that we have found the best way to interact and to deal with industry is to develop with other funding—in this case, NASA funding surrounded then by a larger envelope of—or an equally large envelope of funding from other Government agencies. We found that by building a core program, by building a facility—I don't means bricks and mortar—but building a center, building an organization, building a broad focus of research, that then we were able to have and, of course, bringing in industrial advisers and even consultants and industrial technologists to work with us—we were able to get the critical mass in an area and areas of interest to industry.

Then industry was ready to come in and support our work on three bases: The support of individual specific programs; the support by groups of companies of consortium types of research, even quite basic research, in areas of relevance and importance to their industry; and third, then, simply in the form of—of quite free discretionary, almost grant type moneys to our center in order that we could continue this broad generic work of interest to their industries.

My summary answer to your question is maybe industry could do it, and maybe the universities that wish to set up this program here with NASA funding could get, over a period of time, the money from industry to do the job. But I believe it will be far easier, far quicker and far more effective to build a core with the type of funds we're talking about here, and then, based on that core and based on the critical mass they're able to assemble, to then bring in the industrial support.

Mr. LUJAN. You answered my questions even before I asked them. I was going to ask you what kind of funding you got from industry, whether it was on the specific project or generic and all. And you covered that very well.

Thank you.

Thank you, Mr. Chairman.

Mr. VOLKMER. Does industry make up approximately half of your total funding then?

Dr. FLEMINGS. No. Let me see. Of our current funding of $4 million, 20 percent now comes from NASA—wait a minute, Buzz, I need some help.

Mr. KENNEY. Twenty percent from NASA, 40 percent from industry, and——

Dr. FLEMINGS. And the other 40 percent from other Government agencies.

Mr. VOLKMER. Is the university contributing any?

Dr. FLEMINGS. We—when we talk about this $4 million, this is all money coming in from outside. Now when you say does the university contribute some, yes, but with our accounting system, I'd have to go home and figure out how much before I could—before I could tell you. That's not a number I even think about very often.

Mr. LUJAN. But providing personnel, grant utilities or whatever; that sort of thing?

Dr. FLEMINGS. Absolutely.

Mr. VOLKMER. All right. I was just curious.

The other thing at MIT within the center, do you include graduate programs? In other words——

Dr. FLEMINGS. Yes.

Mr. VOLKMER [continuing]. Credit programs so that they can use it for graduate study?

Dr. FLEMINGS. Yes; most of the research done in the Materials Processing Center, most of the research activities involve graduate students. And on our center-supported research activities, we currently have approximately 50 graduate students working.

Mr. VOLKMER. I would assume that any center that would be set up, center of excellence that we're talking about here, you would probably recommend it also include the use of graduate students; would you not?

Dr. FLEMINGS. I would.

Mr. VOLKMER. Anyone disagree on that?

Dr. Stucki, to follow up a little bit, and also Professor Flemings—and maybe you can tell us what you're doing there now. I have a question in regard to—you know, as we go through research and we have breakthroughs, we have a possibility of something wanting to be patented. Do you envision any problems with the center, and when industry comes in and makes a contribution, as far as patent rights?

Dr. STUCKI. Well, there are always problems, but I think there're always solutions to these problems, too.

Mr. VOLKMER. As you have worked and Upjohn has worked with other universities—and you told us about those. Usually when those agreements are worked out, the question of patents is usually worked out at that time; is it not?

Dr. STUCKI. Yes, that is correct. And I might say that one of the difficulties has been certain attitudes that the—that the Government has had regarding how patents should then be handled if Government has supported the research. And I'm sure you're aware there's a movement toward changing Government attitudes toward——

Mr. VOLKMER. Freeing them up.

Dr. STUCKI [continuing]. Freeing them up, and allowing a certain amount of exclusivity, and so on. So these are the problems and those are the solutions.

But I would—I would—given a willingness to think creatively about such things as exclusivity, and so on, I would see that all of the problems would be amenable to a solution.

Mr. VOLKMER. Can any of you comment on—and we go back to the original—to me, it's almost an assumption now that it should be, the center should be—or the university. Why couldn't we have it at a commercial center, say, a Government laboratory, existing laboratory?

Dr. STUCKI. I would speak for a university center, again reiterating what I said before, because that tends to be the most open kind of a setting. And I think that a combination of openness, participation of students, a willingness to tolerate at the minimum and encourage at the maximum basic research. These are all attributes of the university. They are attributes, but to a lesser extent, of commercial laboratories and Government laboratories. And that's why I support the notion of having this in a research—I mean, in a university rather than a commercial or a Government laboratory.

Mr. VOLKMER. Anyone else wish to comment?

Dr. BIER. I believe that in the bioprocessing area, at least, the involvement of peripheral interest is of paramount importance. The involvement of a medical school, a college of pharmacy, a biochemistry department, a biology department, they all should be—many of them may become contributing members to such a center to some minor or peripheral degree. And by not having the center at the university, you would eliminate this kind of collaboration.

Mr. VOLKMER. All right.

Now, we talked a little bit about the center and then a discussion that may take it even—you know, start up about two years to really get going. How long do you think that we should be involved as far as Government making the core funding? Anybody want to project that?

If not, we'll just let it at that.

Dr. SAVILLE. Well, I'll make a comment.

Mr. VOLKMER. Yes.

Dr. SAVILLE. One way of figuring these things is in terms of the lifetime of a graduate student. So these research projects, most of these things, take 3 or 4 years to accomplish anything of significance. So, if it takes a couple of years to get up to speed, the things that will be accomplished by the permanent research staff will be of one sort, and the things that will be done in terms of doctoral research and the like aren't going to get done for 3 or 4 years. So you are looking at 5 years, I think, as a minimum.

Mr. VOLKMER. As a bare minimum, right, possibly 10 years for a full——

Dr. SAVILLE. Well, I think, you need to have periodic reviews of this. That's one of the functions of this advisory group.

Mr. VOLKMER. Right.

Dr. SAVILLE. Those things need to be examined fairly frequently. But one ought not to expect instant gratification on this.

Mr. VOLKMER. Is there any problem at the MIT—my question—on some of the research that may be necessary, that it may envision the project, at least if it's envision to, say, use of actual microgravity in space for its ultimate end. There's been some discussion that you may start—let's say that someone this year was starting out on a project, graduate students at MIT, and they envision that the ultimate, you know, decision on whether it works or not, it should go up in the shuttle. You may not be able to get on that shuttle for 6 years and that graduate students is going to be gone. Do you see any problem with that?

Dr. FLEMINGS. Well, I don't see—I don't see a problem in that other—other——

Mr. VOLKMER. You just have to have a continuation by the senior——

Dr. FLEMINGS. Yeah. First of all—that's right. The—thesis must be self-contained so that graduate student can graduate. In terms of the funding problem, there obviously must be some continued continuity of funding with the senior investigator who would typically be there for that 6 and 7 and more years.

Mr. VOLKMER. Yes. All right.

Dr. Stucki, I've been given a little paper here that basically says that the recent report from the National Academy of Sciences, just as I'd guess, is falling behind in the pharmaceutical industry. Do you see us catching up any or benefiting any from what we're talking about here today, an eventual possible use of microgravity in space?

Dr. STUCKI. I have not had the privilege of reading the National Academy of Sciences' book. I sent for it, but it's not been available to me yet.

But I have read the—I have read the summaries and summaries of the summaries that appeared here and there. It's my impression from reading those summaries that what the report said was that we were underinvesting in research in the pharmaceutical business as compared to other countries owned industry investments and pharmaceutical research.

To the extent that this constitutes an investment in research, that is of interest to the pharmaceutical industry, I would think that it would have a positive effect, yes.

Mr. VOLKMER. All right.

One last question I have for the panel is that—and perhaps Professor Flemings because you have an ongoing program—is that even though the research being done or would be done at the university, envisions research and processing as far as gravity—where gravity is concerned, or microgravity—that, eventually, it will also assist us even with applications here where gravity is a force in the processing. Everybody agree that——

Dr. BIER. Absolutely.

Mr. VOLKMER [continuing]. That the research could end up with that end?

Dr. BIER. Absolutely.

Mr. VOLKMER. All right.

I may have a couple more here. What's this?

I have a question here. Go back to the question of the university as against the—as against the using of a national lab. The question is, the scientific literature, you know, dissemination emanate sooner since national labs have a technical report format that periodically is done, lead to more dissemination rather than the university setting where you have the peer review concept before publication. One has dissemination sooner than the other. Do you have any comment on that, or disagreement with that?

Dr. **FLEMINGS**. I take it the point, though, is the technology transfer——

Mr. **VOLKMER**. Yes.

Dr. **FLEMINGS** [continuing]. Where the publications is one method of technology transfer.

Mr. **VOLKMER**. Right.

Dr. **FLEMINGS**. I would point out that the most effective method of technology transfer is people, both people from industry coming into this center to learn directly about the techniques and the processes and the developments, and even more important, ultimately the graduate students leaving fired up with—with new knowledge and radical ways of doing things. And they are kind of tough to stop when they get out in industry.

These are—or this general category of technology transfer by exchange of people is an area I think that the universities do particularly well.

Mr. **VOLKMER**. OK. I have no further—any more, Mr. Lujan?

Mr. **LUJAN**. Yes, I have a couple of quick—quick questions.

Dr. Flemings, who else besides NASA—you said 40 percent of your funding comes from others. I assume that—I mean from other Government agencies. I assume that's DOE and some others.

Dr. **FLEMINGS**. That's correct, from a broad spectrum, DOE, DOD, NSF, ONR.

Mr. **LUJAN**. Materials and that sort of thing, new materials that they need.

Dr. **FLEMINGS**. Yes. These programs primarily—well, exclusively—focus toward processing and the development of new materials through processing. It could be hard materials, super-high-strength materials, new electronic materials, and so forth.

Mr. **LUJAN**. One thing that the whole discussion is leading to, and I assume you like that, Dr. Flemings, is a center rather than—our discussion yesterday was funding of universities, plural. Is that where we're headed?

I look at—in some of my other work in committee, we have the—in water law, we have the law of prior appropriation. And, you know, MIT has a materials processing center that already has moved in to corner that—not exactly, I'm exaggerating, I'm sure—but to use as an example, cornering that market. Very aptly named, that's exactly what we need to do. And we're rather sensitive about all the money goes, as the saying goes back home, to—to specific universities.

Are we looking at that? The discussion seems to be drifting to a center that would be established.

Dr. **FLEMINGS**. I can comment very briefly on that. I, in the first place, have no—no thought that this should necessarily be a single university.

I do feel, in programs such as this, that reaching a critical mass is important. Then I think it depends on the amount of funds that are available to be spent and on what is determined by—by—by—

by yourselves, by NASA, by the investigators, as to what constitutes a critical mass.

Mr. **LUJAN**. Does $4 million reach that?

Dr. **FLEMINGS**. $4 million reaches that.

Mr. **LUJAN**. Yes.

Mr. **VOLKMER**. If the gentleman will yield, are we not also possibly limited in the personnel that can be utilized? Anyone wish to comment? In other words, rather than have three or four——

Dr. **FLEMINGS**. I agree.

Mr. **VOLKMER** [continuing]. Centers. And if we're looking at a center of excellence——

Dr. **FLEMINGS**. Certainly initially, that's going to be true.

I think another point to be kept in mind is the establishment of a center ought not to preclude NASA funding and other funding of work in the same or related areas.

Mr. **VOLKMER**. Individuals or——

Dr. **FLEMINGS**. Yes; at other universities or government laboratories. It would be unfortunate, I think, if this were to serve as a strong magnet which would congeal all of the research in one location.

Mr. **LUJAN**. Well, because you could have in another university, of course, somebody working on a particular process that might want to submit their proposal to——

Dr. **FLEMINGS**. Certainly.

Mr. **LUJAN** [continuing]. To NASA.

It would be too bad if we said, sorry, we're going to do everything at MIT.

Dr. **BIER**. If I may add a comment, I think that the existence of a center for such activities will only catalyze greater involvement from other universities with specific research centers, because it will attract national and—and international attention to the existence of a program within which this research is not very widely known or appreciated in the academic community.

So, the establishment of a center of excellence will not be detrimental to research in other universities but, to the contrary, I think will greatly increase the activities in other universities, or at least the total.

Mr. **LUJAN**. Very good point.

Mr. **VOLKMER**. Professor Flemings, I think you covered it somewhere in your statement, but I'd like to ask just for the materials processing center at MIT, are you now—you are, I guess, involved in the crystalization processing——

Dr. **FLEMINGS**. Yes.

Mr. **VOLKMER** [continuing]. Containerless processing meltdown. What about the bio—most of the discussion here has been on the biological end.

Dr. **FLEMINGS**. Our center has not engaged in biological materials up to this point.

Mr. **VOLKMER**. But it has on all the other—all the other aspects of materials processing.

Dr. **FLEMINGS**. Yes, ceramic materials, metallic, polymeric, and electronic materials, inorganic materials, materials that we have been using up to the present time.

Mr. **VOLKMER**. Fine.

I have no further questions.

I want to thank all four of you very much for being here today, and I appreciate your testimony and look forward to maybe reviewing it with you after we get it going and see if you have any problems. We'll see what we can do. We appreciate it.

Dr. **Flemings**. Thank you.

Dr. **Bier**. Thank you.

[Whereupon, at 11:05 a.m., the subcommittee was adjourned.]

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